TMDLS FOR SEGMENTS LISTED FOR MERCURY IN FISH TISSUE FOR SELECTED ARKANSAS WATERSHEDS

September 17, 2002

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Prepared for

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EXECUTIVE SUMMARY

The Arkansas 1998 Section 303(d) List included stream reaches that were impaired due to excessive concentrations of mercury in fish. This TMDL study addresses 5 of the listed stream reaches. In addition, 8 lakes in Arkansas and 1 additional river reach are under fish consumption advisories as a result of high mercury concentrations in fish. These waterbodies are also addressed in this TMDL study. While there have been no known violations of the numeric mercury water quality standard and fishable designated use for these waterbodies, they are not meeting the narrative water quality standard and designated uses of fishable waterbodies.

The waterbodies included in this TMDL study are located predominantly in central and northern Arkansas, although there are a couple in the southwest corner of the state. Waterbodies that were close together and had similar watershed characteristics were grouped together because of similar causative factors such as atmospheric and geologic contributions. As a result, TMDLs were completed for 5 watersheds that included the waterbodies of interest for this study.

Arkansas has a numeric mercury water quality standard of 0.012 μg/L. There have been no known violations of this numeric mercury water quality standard in any of the waterbodies included in this TMDL study, but clean sampling procedures and ultra-trace level analyses have not been used. There are fish consumption advisories in all of these waterbodies because of mercury contamination of fish. The mercury Action Level for fish consumption advisories in Arkansas is 1 mg/kg. The safe target level for all fish species used in this TMDL study is 0.8 mg/kg. This incorporates a 20% margin of safety (MOS) for the Action Level.

The TMDLs were developed using a two step approach. The first step was to estimate the mercury loads to the watersheds from NPDES point sources, local emission sources, atmospheric deposition from non-local emission sources, watershed nonpoint sources, and watershed natural background sources. In the second step, average largemouth bass fish tissue mercury concentrations measured in the watersheds were used to estimate the reduction in fish tissue mercury needed to achieve the safe target level. A linear relationship was assumed between mercury levels in fish and mercury loading to the watersheds. The reduction in fish tissue mercury to achieve the target safe level was then used to determine the reduction needed in the mercury load to the watersheds.

The predominant sources of mercury loading to the watersheds were watershed nonpoint sources, watershed natural background, and non-local source atmospheric deposition. NPDES point sources accounted for less than 1% of the watershed mercury loads. Half of the watersheds did not have NPDES point sources of mercury. Watershed reduction factors for mercury loads ranged from 1.02 to 3.2. Even with these reductions, the character of mercury bioaccumulation makes it likely to be a long time before reductions in fish mercury levels are seen as a result of reduced loads to the watersheds.

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1.0 INTRODUCTION

The Arkansas 1998 Section 303(d) List included waterbodies impaired due to excessive concentrations of mercury in fish. Stream reaches listed for mercury in the Ouachita River basin in Arkansas were addressed in a separate TMDL study (FTN 2002). The current TMDL study addresses the remaining stream reaches listed for mercury in Arkansas. This TMDL study also addresses waterbodies where fish consumption advisories have been issued by the State of Arkansas. Table 1.1 identifies the stream reaches and lakes included in this TMDL study.

Figure 1.1 identifies the hydrologic unit category (HUC) watersheds that contain the waterbodies included in the current TMDL study (Note: all figures are located at the end of each section). Table 1.2 lists the HUCs that contain the waterbodies that are included in this TMDL study. The Loggy Bayou HUC, which includes Bayou Dorcheat and Columbia Lake, extends into Louisiana. The Louisiana Bayou Dorcheat stream reaches (subsegments) have been delisted for mercury (Louisiana 1999 Court Ordered Modified 303(d) List). Therefore, only the portion of Bayou Dorcheat upstream of the Arkansas-Louisiana state line is included in this TMDL study.

These segments are of critical concern because of litigation over the 303(d) process in Arkansas, and the pervasiveness of mercury contamination. While there have been no known violations of the numeric water quality standards and fishable designated use for these waterbodies, these segments are not meeting the narrative water quality standard and designated uses of fishable waterbodies. Therefore, development of a TMDL is required. This TMDL is being conducted under EPA Contract #68-C-99-249, Work Assignment #1-85.

Table 1.1. River segments and lakes on 303(d) List or where fish consumption advisories have been issued.

Waterbody Name	Segment / Reach	On 303(d) List	Fish Consumption Advisory	Priority
Bayou Dorcheat	11140203-020	Yes	Yes	Low
	11140203-022	Yes	Yes	Low
	11140203-024	Yes	Yes	Low
	11140203-026	Yes	Yes	Low
Fourche La Fave River	11110206-002	Yes	Yes	Low
South Fork Little Red River	11010014-036	No	Yes	—
Columbia Lake	—	No	Yes	—
Cove Creek Lake	—	No	Yes	—
Dry Fork Lake	—	No	Yes	—
Nimrod Lake	—	No	Yes	—
Johnson Hole	—	No	Yes	—
Shepherd Springs Lake	—	No	Yes	—
Spring Lake	—	No	Yes	—
Lake Sylvia	—	No	Yes	—
Lake Winona	—	No	Yes	—

Table 1.2. HUC number, name, and associated segments or waterbodies included in this TMDL.

Hydrologic Unit Category	**HUC Name**	**Segments or Waterbodies in TMDL**
11110206	Fourche La Fave	Fourche La Fave River, Lake Nimrod, Dry Fork Lake, Cove Creek Lake
11140203	Loggy Bayou	Bayou Dorcheat, Lake Columbia
11010014	Little Red	South Fork Little Red River, Johnson Hole
11110201	Frog-Mulberry	Shepherd Springs Lake
11110207	Lower Arkansas-Maumelle	Spring Lake, Lake Sylvia
08040203	Upper Saline	Lake Winona

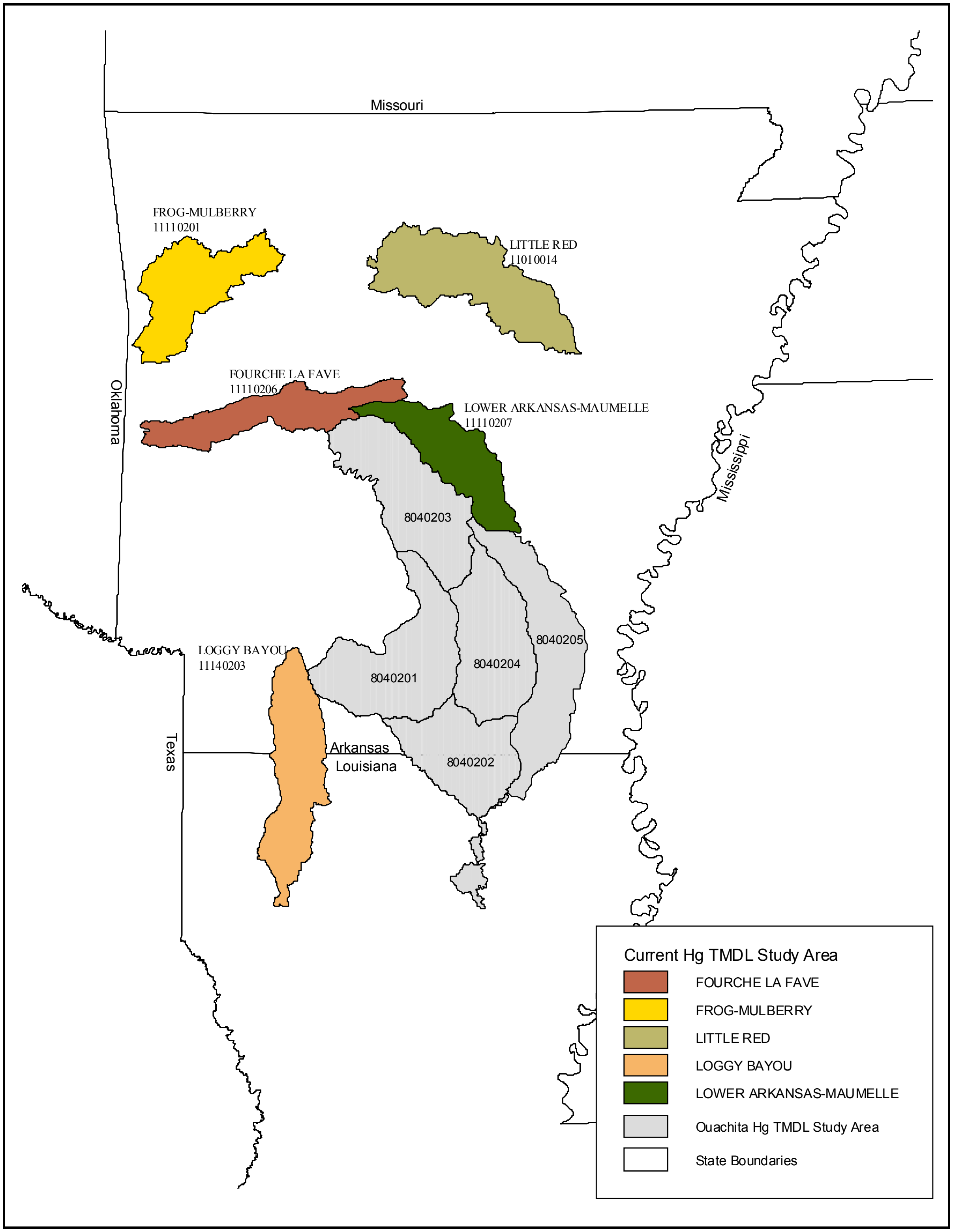


Figure 1.1. Hydrologic unit categories that contain segments or waterbodies included in this TMDL.

2.0 DESCRIPTION OF WATERBODIES

The TMDL development is based on a watershed approach because of similar causative factors, such as atmospheric and geologic contributions. This TMDL complements and is consistent with the previous mercury TMDL developed for the Ouachita River (FTN 2002). The remaining waters in Arkansas listed for mercury in fish on the 303(d) List, or where fish consumption advisories have been issued by the state, have been grouped into six watersheds. A TMDL has been developed for each of the watersheds. The characteristics of the watersheds are described below.

2.1 Fourche La Fave Watershed

The Fourche La Fave watershed has been defined to include Fourche La Fave River and its tributaries located within the HUC 11110206 (Figure 2.1). This watershed includes listed portions of Fourche La Fave River, as well as Dry Fork Lake, Lake Nimrod, and Cove Creek Lake. The headwaters of the Fourche La Fave River begin in the southern portion of Scott County, Arkansas in the Ouachita Mountains. The Fourche La Fave River runs from west to east through Scott County, Yell County, and Perry County before emptying into the Arkansas River at the eastern edge of Perry County. The watershed drainage area covers approximately 715,690 acres (2,893 km^2) of land located within both the Ouachita Mountains and the Arkansas River Valley. The waters within the Fourche La Fave River watershed have been designated by ADEQ as suitable for the propagation of fish/wildlife, primary and secondary contact recreation and public, industrial and agricultural water supplies.

2.1.1 Topography

The following description of the topography of the watershed was taken from county soil surveys (USDA 1982, 1988, 1998). The watershed is in the Ouachita Mountains and Arkansas River Valley. The topography of this area can be described as level to very steep, with the main topographic divisions consisting of uplands, mountains, ridges, terraces, and flood plains, with slope ranges from 1% to 40%.

2.1.2 Soils

Soil characteristics for the watershed were taken from the county soil surveys (USDA 1982, 1988, 1998). Most of the soils in the watershed are classified as moderately well drained to well drained gravelly, cobbly, stony, very stony, and loamy soils on uplands and mountains. Soil associations that are most common in the watershed include Carnasaw-Sherless-Clebit and Carnasaw-Pirum-Clebit. Other soil associations that are somewhat common include Guthrie-Barling, Avilla-Kenn-Ceda, Spadra-Barling-Pickwick, Leadvale-Cane-Taft, Leadvale-Guthrie, Perry-Moreland, Muskogee-Wrightsville-McKamie, Leadvale-Endsaw-Taft, Spadra-Neff-Cupco, Kenn-Avilla-Ceda, and Octavia-Caston-Carnasaw.

2.1.3 Land Use

Land use in the watershed is predominantly forest land and some agricultural land (Figure 2.2). Areas and approximate percentages of each land use in the watershed are listed in Table 2.1. Most of the lowlands have been cleared, and on most farms drainage has been improved for more reliable crop production. Soybeans are the main crop grown on the bottom lands, but rice, wheat, and sorghums are also grown. Much of the farm income is from livestock, mainly beef cattle, poultry, and hogs. Portions of the forest land are owned by large timber companies and some areas are federally administered land within the Ouachita National Forest.

2.1.4 Description of Hydrology

USGS daily stream flow data were retrieved for the gage in the Fourche La Fave River near Gravelly, Arkansas. Basic information and summary statistics for the gage are summarized in Table 2.2.

Table 2.1. Acreage and percent of land use categories in the Fourche La Fave River watershed.

Land Use	Acres (km^2)	Percent
Forest	601,260 (2,430)	84.0
Agricultural	106,200 (430)	14.8
Wetland	780 (3)	0.1
Water	5,800 (23)	0.8
Urban	1,610 (7)	0.2
Other	30 (0.1)	0.004
TOTAL	715,690 (2,893)	100

Table 2.2. Information for stream flow gage station, Fourche La Fave River.

Gage name	Fourche La Fave River near Gravelly, AR
USGS gage number	07261500
Descriptive location	Latitude 34°52'21" Longitude 93°39'24" Located in Yell County near left bank on downstream side of bridge on State Highway 28
Drainage area	410 mi^2
Period of record	October 1987 to September 2000
Mean flow	604 ft^3/sec
Minimum flow	0.0 ft^3/sec
Maximum flow	44,800 ft^3/sec
Flow that is exceeded: 80% of the time 50% of the time 20% of the time	 10 ft^3/sec 159 ft^3/sec 681 ft^3/sec

Average annual precipitation for the watershed is approximately 52 inches (Hydrosphere 2000). Mean monthly precipitation totals for the watershed are shown in Figure 2.3. The mean monthly precipitation values are highest for December and lowest for August. Precipitation data for 1997 through 1999 from three stations within HUC 11110206 were used to calculate the annual and monthly mean precipitation for the watershed (Appendix A).

2.1.5 Point Sources

Information on NPDES point source discharges in the watershed was obtained by searching the PCS on the EPA website. The PCS search identified 3 facilities with NPDES permits within the watershed, which were municipal wastewater treatment systems that discharge within the Fourche La Fave River watershed. A listing of NPDES permitted facilities is included in Appendix B.

Information on local air emission sources in the airshed (airshed defined to include counties within 100 km of the watershed boundary) was obtained by searching the EPA Office of Air Quality Planning and Standards National Toxics Inventory (NTI) emission database on the EPA website. The NTI emission inventory includes point sources, area sources, and mobile sources. Data from the NTI website was downloaded using the maxiumum achievable control technology (MACT) report format. The MACT report includes the number of point sources and 1996 total hazardous air pollutant (HAP) emissions for each MACT source category included in the NTI by county. The database search for the airshed resulted in 217 air emission sources in 10 MACT source categories. The MACT source categories are based on standards for emission limitations developed under section 112(d) of the Clean Air Act (National Emissions Standards for Hazardous Air Pollutants). The limitations are based on the best demonstrated control technology or practices in similar sources to be applied to major sources emitting one or more of the listed toxic pollutants. A listing of the air emission sources is included in Appendix C.

2.2 Bayou Dorcheat Watershed

The Bayou Dorcheat watershed has been defined to include Bayou Dorcheat and its tributaries located within the HUC 11140203 north of the Arkansas-Louisiana state line (Figure 2.4). It includes listed portions of Bayou Dorcheat, as well as Lake Columbia. The headwaters of Bayou Dorcheat begin in southern Nevada County and northern Columbia County, Arkansas in the Gulf Coastal Plain ecoregion. Bayou Dorcheat runs from north to south through Columbia County, Arkansas and continues into Webster Parish, Louisiana before emptying into Lake Bistineau south of Minden, Louisiana. The watershed drainage area covers approximately 324,106 acres (1,312 km^2) of land located within the Gulf Coastal Plain ecoregion. The waters within the Bayou Dorcheat watershed have been designated by ADEQ as suitable for the propagation of fish/wildlife, primary and secondary contact recreation and public, industrial and agricultural water supplies.

2.2.1 Topography

The following description of the topography of the watershed was taken from county soil surveys (USDA 1985). The watershed is in the Gulf Coastal Plain ecoregion. The topography of this area can be described as level to moderately sloping, with the main topographic divisions consisting of upland flats, flood plains, low terraces, hilltops, and side slopes, with slope ranges from 0% to 12%.

2.2.2 Soils

Soil characteristics for the watershed were taken from the county soil surveys (USDA 1985). Most of the soils in the watershed are classified as poorly drained to moderately well drained loamy soils on upland flats, flood plains, low terraces, hilltops, and side slopes. Soil associations that are most common in the watershed include Bowie-Sacul, Harleston-Bowie, Guyton, and Felker-Adaton. Other soil associations that are somewhat common include Wrightsville-Louin, Sacul-Smithdale, and Smithdale.

2.2.3 Land Use

Land use in the watershed is predominantly forest land and agricultural land (Figure 2.5). Areas and approximate percentages of each land use in the watershed are listed in Table 2.3. The timber industry is an important part of the economy. A large acreage is managed for the production of pulpwood, poles, and saw logs. Most of the remaining land is used for pasture and forage crops. Livestock production and poultry production are also economically important in the area.

Table 2.3. Acreage and percent of land use categories in the Bayou Dorcheat watershed.

Land Use	Acres (km^2)	Percent
Forest	222,048 (899)	68.8
Agricultural	62,946 (255)	19.5
Wetland	32,986 (133)	10.2
Water	120(0.49)	0.04
Urban	4,667 (18.9)	1.4
Other	150 (0.61)	0.05
TOTAL	324,106 (1,312)	100

2.2.4 Description of Hydrology

USGS daily stream flow data were retrieved for the gage in the Bayou Dorcheat near Springhill, Louisiana. Basic information and summary statistics for the gage are summarized in Table 2.4.

Table 2.4. Information for stream flow gage station, Bayou Dorcheat.

Gage Name	Bayou Dorcheat near Springhill, LA
USGS gage number	07348700
Descriptive location	Latitude 32°59'40" Longitude 93°23'47" Located in Webster Parish near Springhill, LA
Drainage area	605 mi^2
Period of record	October 1957 to September 1998
Mean flow	617 ft^3/sec
Minimum flow	0.0 ft^3/sec
Maximum flow	35,000 ft^3/sec
Flow that is exceeded: 80% of the time 50% of the time 20% of the time	 10 ft^3/sec 134 ft^3/sec 900 ft^3/sec

Average annual precipitation for the watershed is approximately 61 inches (Hydrosphere 2000). Mean monthly precipitation totals for the watershed are shown in Figure 2.6. The mean monthly precipitation values are highest for January and lowest for July. Precipitation data for 1997 through 1999 from three stations within HUC 11140203 were used to calculate the annual and monthly mean precipitation for the watershed (Appendix A).

2.2.5 Point Sources

Information on NPDES point source discharges in the watershed was obtained by searching the PCS on the EPA website. The PCS search identified 10 facilities with NPDES permits within the watershed. Of these 10 permitted facilities, 4 were municipal wastewater treatment systems that discharge into the Bayou Dorcheat watershed. The remaining 6 NPDES permitted facilities were for commercial/industrial sources and did not have a permit limit for mercury. A listing of NPDES permitted facilities is included in Appendix B.

Information on local air emission sources in the airshed (airshed defined to include counties within 100 km of the watershed boundary) was obtained by searching the EPA Office of Air Quality Planning and Standards National Toxics Inventory (NTI) emission database on the EPA website. The NTI emission inventory includes point sources, area sources, and mobile sources. Data from the NTI website was downloaded using the maxiumum achievable control technology (MACT) report format. The MACT report includes the number of point sources and total 1996 hazardous air pollutant (HAP) emissions for each MACT source category included in the NTI by county. The database search for the airshed resulted in 185 air emission sources in 12 MACT source categories. The MACT source categories are based on standards for emission limitations developed under section 112(d) of the Clean Air Act (National Emissions Standards for Hazardous Air Pollutants). The limitations are based on the best demonstrated control technology or practices in similar sources to be applied to major sources emitting one or more of the listed toxic pollutants. A listing of the air emission sources is included in Appendix C.

2.3 South Fork Little Red Watershed

The South Fork Little Red watershed has been defined to include the South Fork Little Red River and its tributaries located within the HUC 11010014 (Figure 2.7). It includes listed portions of the South Fork Little Red River, as well as Johnson Hole. The headwaters of the South Fork Little Red River begin in the western portion of Van Buren County, Arkansas in the Boston Mountains. The South Fork Little Red River runs from west to east through Van Buren County, Arkansas before emptying into Greers Ferry Lake near Clinton, Arkansas. The watershed drainage area covers approximately 177,212 acres (717 km^2) of land located within the Boston Mountains. The waters within the South Fork Little Red River watershed have been designated by ADEQ as suitable for the propagation of fish/wildlife, primary and secondary contact recreation and public, industrial and agricultural water supplies.

2.3.1 Topography

The following description of the topography of the watershed was taken from county soil surveys (USDA 1986). The watershed is in the Boston Mountains. The topography of this area can be described as broad, gently sloping to rolling mountaintops and steep to very steep mountainsides. The mountaintops are generally capped with hard sandstone, and the mountainsides are typically interbedded sandstone, siltstone, and shale. Slope ranges from 1% to 60%.

2.3.2 Soils

Soil characteristics for the watershed were taken from the county soil surveys (USDA 1986). Most of the soils in the watershed are classified as well drained loamy, gravelly, and stony soils that formed in residual and colluvial material derived from shale or interbedded sandstone, siltstone, and shale. Soil associations that are most common in the watershed include Enders-Steprock-Nella, Steprock-Mountainburg-Rock Outcrop, Linker-Steprock, and Kenn-Ceda-Spadra.

2.3.3 Land Use

Land use in the watershed is predominantly forest land and agricultural land (Figure 2.8). Areas and approximate percentages of each land use in the watershed are listed in Table 2.5. Dairy herds, beef cattle, hogs, and poultry provide most of the farm income in the area of ridges, upland flats, and valleys. Some farms have small acreage of orchards, vegetables, strawberries, or a combination of these. On the bottom lands, soybeans are the main crop, but grain sorghum and winter small grains are also grown.

Table 2.5. Acreage and percent of land use categories in the South Fork Little Red watershed.

Land Use	Acres (km^2)	Percent
Forest	153,910 (622)	86.9
Agricultural	21,572 (87)	12.2
Wetland	—	—
Water	279 (1.1)	0.2
Urban	1,451 (5.9)	0.8
Other	—	—
TOTAL	177, 212 (717)	100

2.3.4 Description of Hydrology

USGS daily stream flow data were retrieved for the gage in the South Fork Little Red River at Clinton, Arkansas. Basic information and summary statistics for the gage are summarized in Table 2.6.

Average annual precipitation for the watershed is approximately 48 inches (Hydrosphere 2000). Mean monthly precipitation totals for the watershed are shown in Figure 2.9. The mean monthly precipitation values are highest for March and lowest for August. Precipitation data for 1997 through 1999 from three stations within HUC 11010014 were used to calculate the annual and monthly mean precipitation for the watershed (Appendix A).

Table 2.6. Information for stream flow gage station, South Fork Little Red River.

Gage Name	South Fork Little Red River at Clinton, AR
USGS gage number	07075300
Descriptive location	Latitude 35°35'29" Longitude 92°27'20" Located in Van Buren County near right bank on upstream side of bridge on US Highway 65 at Clinton
Drainage area	148 mi^2
Period of record	March 1939 to December 1961
Mean flow	579 ft^3/sec
Minimum flow	0.0 ft^3/sec
Maximum flow	29,400 ft^3/sec
Flow that is exceeded: 80% of the time 50% of the time 20% of the time	 15 ft^3/sec 170 ft^3/sec 735 ft^3/sec

2.3.5 Point Sources

Information on NPDES point source discharges in the watershed was obtained by searching the PCS on the EPA website. The PCS search identified 24 facilities with NPDES permits within the watershed. Of these 24 permitted facilities, 2 were municipal wastewater treatment systems that discharge within the South Fork Little Red watershed. The remaining 22 NPDES permitted facilities were for commercial/industrial sources and did not have a permit limit for mercury. A listing of NPDES permitted facilities is included in Appendix B.

Information on local air emission sources in the airshed (airshed defined to include counties within 100 km of the watershed boundary) was obtained by searching the EPA Office of Air Quality Planning and Standards National Toxics Inventory (NTI) emission database on the EPA website. The NTI emission inventory includes point sources, area sources, and mobile sources. Data from the NTI website was downloaded using the maxiumum achievable control technology (MACT) report format. The MACT report includes the number of point sources and total 1996 hazardous air pollutant (HAP) emissions for each MACT source category included in the NTI by county. The database search for the airshed resulted in 132 air emission sources in

8 MACT source categories. The MACT source categories are based on standards for emission limitations developed under section 112(d) of the Clean Air Act (National Emissions Standards for Hazardous Air Pollutants). The limitations are based on the best demonstrated control technology or practices in similar sources to be applied to major sources emitting one or more of the listed toxic pollutants. A listing of the air emission sources is included in Appendix C.

2.4 Shepherd Springs Lake Watershed

The Shepherd Springs Lake watershed has been defined to include Shepherd Springs Lake and its tributaries located within the HUC 11110201 (Figure 2.10). Shepherd Springs Lake and its tributaries are located in the northeastern portion of Crawford County, Arkansas. The watershed drainage area covers approximately 44,908 acres (182 km^2) of land located within the Boston Mountains. Shepherd Springs Lake has been designated by ADEQ as suitable for the propagation of fish/wildlife, primary and secondary contact recreation and public, industrial and agricultural water supplies.

2.4.1 Topography

The following description of the topography of the watershed was taken from county soil surveys (USDA 1979). The Shepherd Springs Lake watershed is in the Boston Mountains. The topography of this area can be described as steep, stony mountains. These mountains are capped by sandstone, and their sides interbedded sandstone and shale. Slope ranges from 3 to 50% and elevation ranges from about 500 to 2,380 feet.

2.4.2 Soils

Soil characteristics for the watershed were taken from the county soil survey (USDA 1979). Most of the soils in the Shepherd Springs Lake watershed are classified as well drained, gently sloping to very steep, deep, loamy and stony soils on hills and mountains. The main soil association that is common in the watershed is the Nella-Enders. Nella soils are on toeslopes and benches, and Enders soils are on hillsides and mountainsides.

2.4.3 Land Use

Land use in the watershed is predominantly forest land (Figure 2.11). Areas and approximate percentages of each land use in the watershed are listed in Table 2.7.

Table 2.7. Acreage and percent of land use categories in the Shepherd Springs Lake watershed.

Land Use	Acres (km^2)	Percent
Forest	40,533 (164)	90.3
Agricultural	3,936 (16)	8.8
Wetland	---	---
Water	270 (1.1)	0.6
Urban	169 (0.7)	0.3
Other	---	
TOTAL	44,908 (182)	100

The soils in most of this area are too steep for intensive farming use. They are used mainly for the production of wood crops and for native pasture. Some of the less sloping soils are suitable for improved pasture, and the soils in some of the narrow valleys are suitable for truck crops.

2.4.4 Description of Hydrology

Average annual precipitation for the watershed is approximately 53 inches (Hydrosphere 2000). Mean monthly precipitation totals for the watershed are shown in Figure 2.12. The mean monthly precipitation values are highest for March and lowest for August. Precipitation data for 1997 through 1999 from three stations within HUC 11110201 were used to calculate the annual and monthly mean precipitation for the watershed (Appendix A). USGS daily stream flow data were not available for this watershed.

2.4.5 Point Sources

Information on NPDES point source discharges in the watershed was obtained by searching the PCS on the EPA website. Based on information from the PCS search, there were no facilities identified with NPDES permits within the watershed.

Information on local air emission sources in the airshed (airshed defined to include counties within 100 km of the watershed boundary) was obtained by searching the EPA Office of Air Quality Planning and Standards National Toxics Inventory (NTI) emission database on the EPA website. The NTI emission inventory includes point sources, area sources, and mobile sources. Data from the NTI website was downloaded using the maxiumum achievable control technology (MACT) report format. The MACT report includes the number of point sources and total 1996 hazardous air pollutant (HAP) emissions for each MACT source category included in the NTI by county. The database search for the airshed resulted in 119 air emission sources in 8 MACT source categories. The MACT source categories are based on standards for emission limitations developed under section 112(d) of the Clean Air Act (National Emissions Standards for Hazardous Air Pollutants). The limitations are based on the best demonstrated control technology or practices in similar sources to be applied to major sources emitting one or more of the listed toxic pollutants. A listing of the air emission sources is included in Appendix C.

2.5 Spring Lake Watershed

For this TMDL, the Spring Lake watershed has been defined to include Spring Lake and its tributaries located within the HUC 11110207 (Figure 2.13). Spring Lake and its tributaries are located in the southeastern portion of Saline County, Arkansas. The watershed drainage area covers approximately 23,555 acres (95 km^2) of land located within the Gulf Coastal Plain ecoregion. Spring Lake has been designated by ADEQ as suitable for the propagation of fish/wildlife, primary and secondary contact recreation and public, industrial and agricultural water supplies.

2.5.1 Topography

The following description of the topography of the watershed was taken from county soil surveys (USDA 1979). The Spring Lake watershed is in the Gulf Coastal Plain ecoregion. The topography of this area can be described as level to moderately sloping uplands, with slope ranges from 3% to 8%.

2.5.2 Soils

Soil characteristics for the watershed were taken from the county soil survey (USDA 1979). Most of the soils in the watershed are classified as poorly drained to well drained loamy soils. Soil associations that are common in the watershed include Smithdale-Savannah-Amy and Tiak-Savannah.

2.5.3 Land Use

Land use in the watershed is predominantly forest land (Figure 2.14). Areas and approximate percentages of each land use in the watershed are listed in Table 2.8. Some areas are suitable for improved pasture and cultivated crops. Excess water is a moderate to very severe hazard on the level tracts. Erosion is a moderate to very severe hazard in the more sloping areas.

Table 2.8. Acreage and percent of land use categories in the Spring Lake watershed.

Land Use	Acres (km^2)	Percent
Forest	2,429 (9.8)	88.1
Agricultural	16 (0.1)	0.6
Wetland	0 (0)	0.0
Water	158 (0.6)	5.8
Urban	69 (0.3)	2.5
Other	63 (0.2)	2.3
TOTAL	2,735 (11.1)	100

2.5.4 Description of Hydrology

Average annual precipitation for the watershed is approximately 47 inches (Hydrosphere 2000). Mean monthly precipitation totals for the watershed are shown in Figure 2.15. The mean monthly precipitation values are highest for March and lowest for July. Precipitation data for 1997 through 1999 from three stations within HUC 11110207 were used to calculate the annual and monthly mean precipitation for the watershed (Appendix A). USGS daily stream flow data were not available for this watershed.

2.5.5 Point Sources

Information on NPDES point source discharges in the watershed was obtained by searching the PCS on the EPA website. Based on information from the PCS search, there were no facilities identified with NPDES permits within the watershed.

Information on local air emission sources in the airshed (airshed defined to include counties within 100 km of the watershed boundary) was obtained by searching the EPA Office of Air Quality Planning and Standards National Toxics Inventory (NTI) emission database on the EPA website. The NTI emission inventory includes point sources, area sources, and mobile sources. Data from the NTI website was downloaded using the maxiumum achievable control technology (MACT) report format. The MACT report includes the number of point sources and total 1996 hazardous air pollutant (HAP) emissions for each MACT source category included in the NTI by county. The database search for the airshed resulted in 113 air emission sources in 9 MACT source categories. The MACT source categories are based on standards for emission limitations developed under section 112(d) of the Clean Air Act (National Emissions Standards for Hazardous Air Pollutants). The limitations are based on the best demonstrated control technology or practices in similar sources to be applied to major sources emitting one or more of the listed toxic pollutants. A listing of the air emission sources is included in Appendix C.

2.6 Lake Winona and Lake Sylvia Watershed

For this TMDL, the Lake Winona and Lake Sylvia watersheds have been combined because of their close proximity and similar land uses. The Lake Winona watershed has been defined to include Lake Winona and its tributaries located within the HUC 08040203 (Figure 2.16). Lake Winona and its tributaries are located in the northern portion of Saline County, Arkansas. The watershed drainage area covers approximately 28,810 acres (117 km^2) of land located within the Ouachita Mountains. The Lake Sylvia watershed has been defined to include Lake Sylvia and its tributaries located within the HUC 11110207 (Figure 2.19). Lake Sylvia and its tributaries are located within the southeastern portion of Perry County, Arkansas. The watershed drainage area covers approximately 5,510 acres (22 km^2) of land located within the Ouachita Mountains. These lakes have been designated by ADEQ as suitable for the propagation of fish/wildlife, primary and secondary contact recreation and public, industrial and agricultural water supplies.

2.6.1 Topography

The following description of the topography of the watersheds was taken from county soil surveys (USDA 1979). The Lake Winona and Lake Sylvia watersheds are in the Ouachita Mountains. The topography of this area can be described as gently sloping to very steep ridges, crests, and side slopes, with slope ranges from 1% to 60%.

2.6.2 Soils

Soil characteristics for the watersheds were taken from county soil surveys (USDA 1979). Most of the soils in the watersheds are classified as poorly drained to well drained loam, gravelly loam, stony soil, and soils developed from sandstone and shale. Soil associations that are common in the watershed include Carnasaw-Townley-Pirum, Carnasaw-Pirum-Clebit, and Leadvale-Guthrie.

2.6.3 Land Use

Land use in the watersheds is predominantly forest land (Figure 2.17). Areas and approximate percentages of each land use in the watersheds are listed in Table 2.9. Most areas are mainly used for timber production. Steep slopes, available water capacity, depth to bedrock, stony or gravelly surface layer, and the severe hazard of erosion are the main limitations for plants.

Table 2.9. Acreage and percent of land use categories in the Lake Winona and Lake Sylvia watersheds.

Land Use	Acres (km^2)	Percent
Forest	33,048 (134)	96.3
Agricultural	---	---
Wetland	---	---
Water	1,272 (5.1)	3.7
Urban	---	---
Other	---	---
TOTAL	34,320 (139)	100

2.6.4 Description of Hydrology

Average annual precipitation for the watersheds is approximately 50 inches (Hydrosphere 2000). Mean monthly precipitation totals for the watersheds are shown in Figure 2.18. The mean monthly precipitation values are highest for March and lowest for August. Precipitation data for 1997 through 1999 from three stations within HUC 11110207 and three stations within HUC 08040203 were used to calculate the annual and monthly mean precipitation for the watershed (Appendix A). USGS daily stream flow data were not available for this watershed.

2.6.5 Point Sources

Information on NPDES point source discharges in the watersheds was obtained by searching the PCS on the EPA website. Based on information from the PCS search, there were no facilities identified with NPDES permits within the watersheds.

Information on local air emission sources in the airshed (airshed defined to include counties within 100 km of the watershed boundary) was obtained by searching the EPA Office of Air Quality Planning and Standards National Toxics Inventory (NTI) emission database on the EPA website. The NTI emission inventory includes point sources, area sources, and mobile sources. Data from the NTI website was downloaded using the maxiumum achievable control technology (MACT) report format. The MACT report includes the number of point sources and total 1996 hazardous air pollutant (HAP) emissions for each MACT source category included in the NTI by county. The database search for the airshed resulted in 128 air emission sources in 9 MACT source categories. The MACT source categories are based on standards for emission limitations developed under section 112(d) of the Clean Air Act (National Emissions Standards for Hazardous Air Pollutants). The limitations are based on the best demonstrated control technology or practices in similar sources to be applied to major sources emitting one or more of the listed toxic pollutants. A listing of the air emission sources is included in Appendix C.

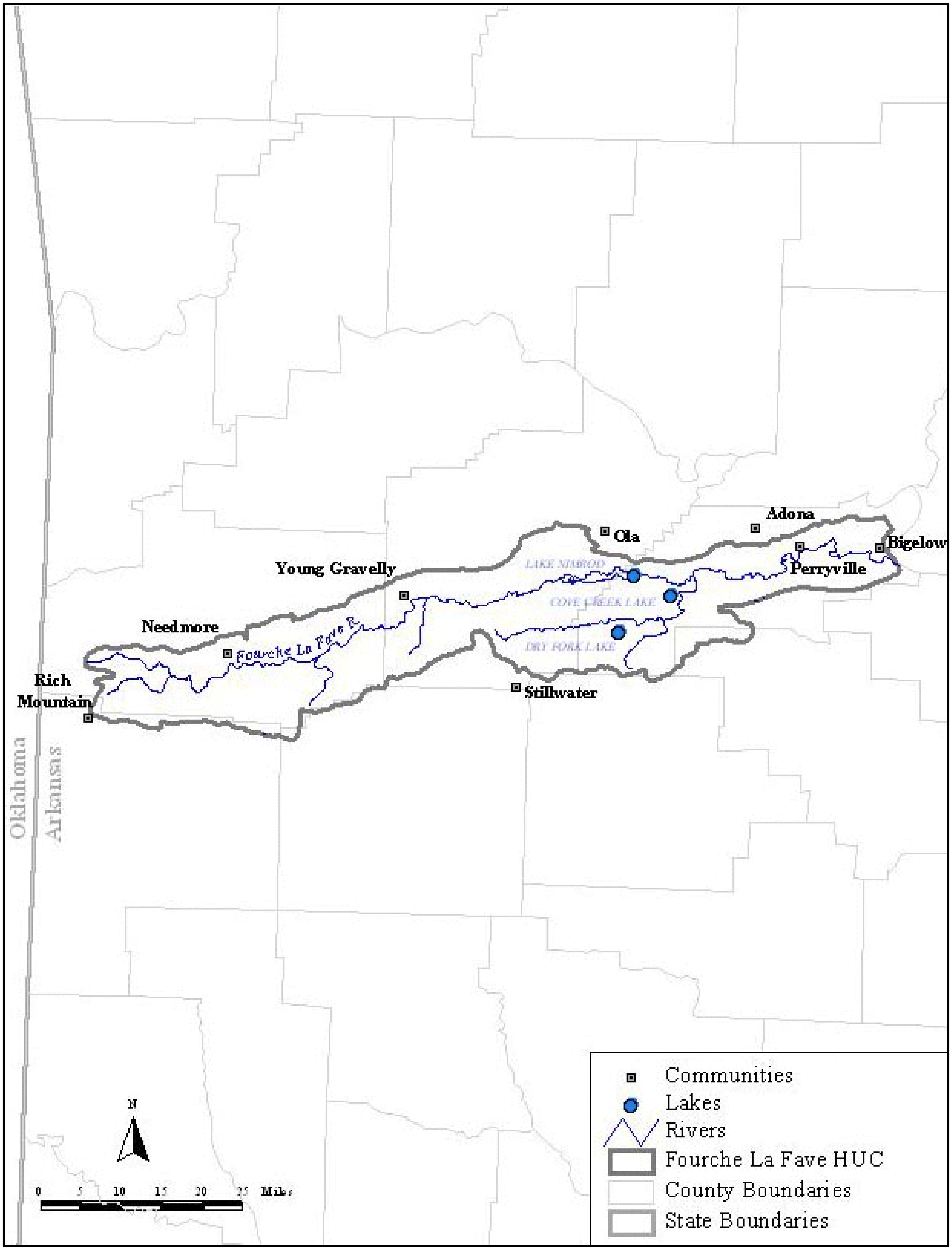


Figure 2.1. Fourche La Fave HUC 11110206.

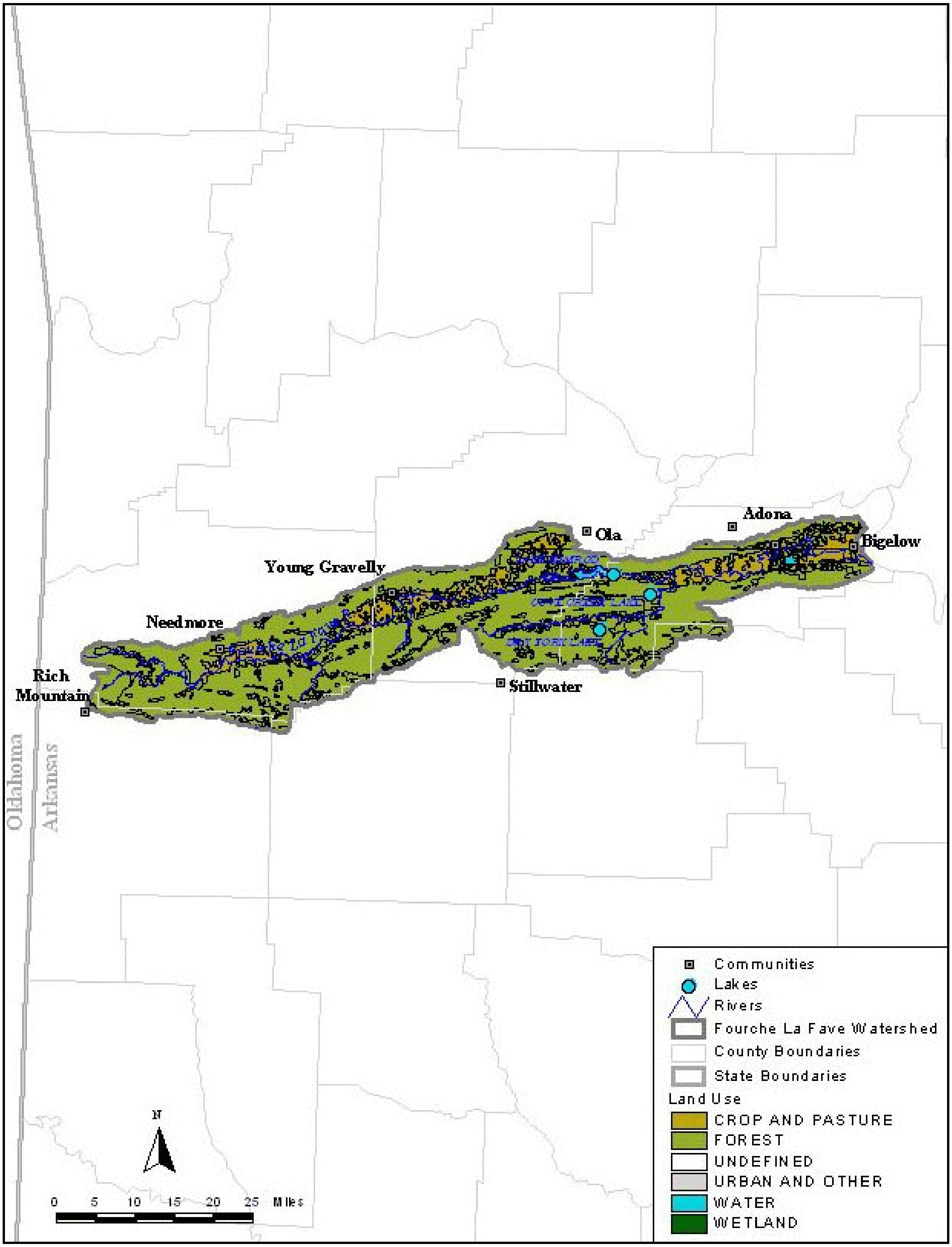


Figure 2.2. Fourche La Fave watershed major land use categories.

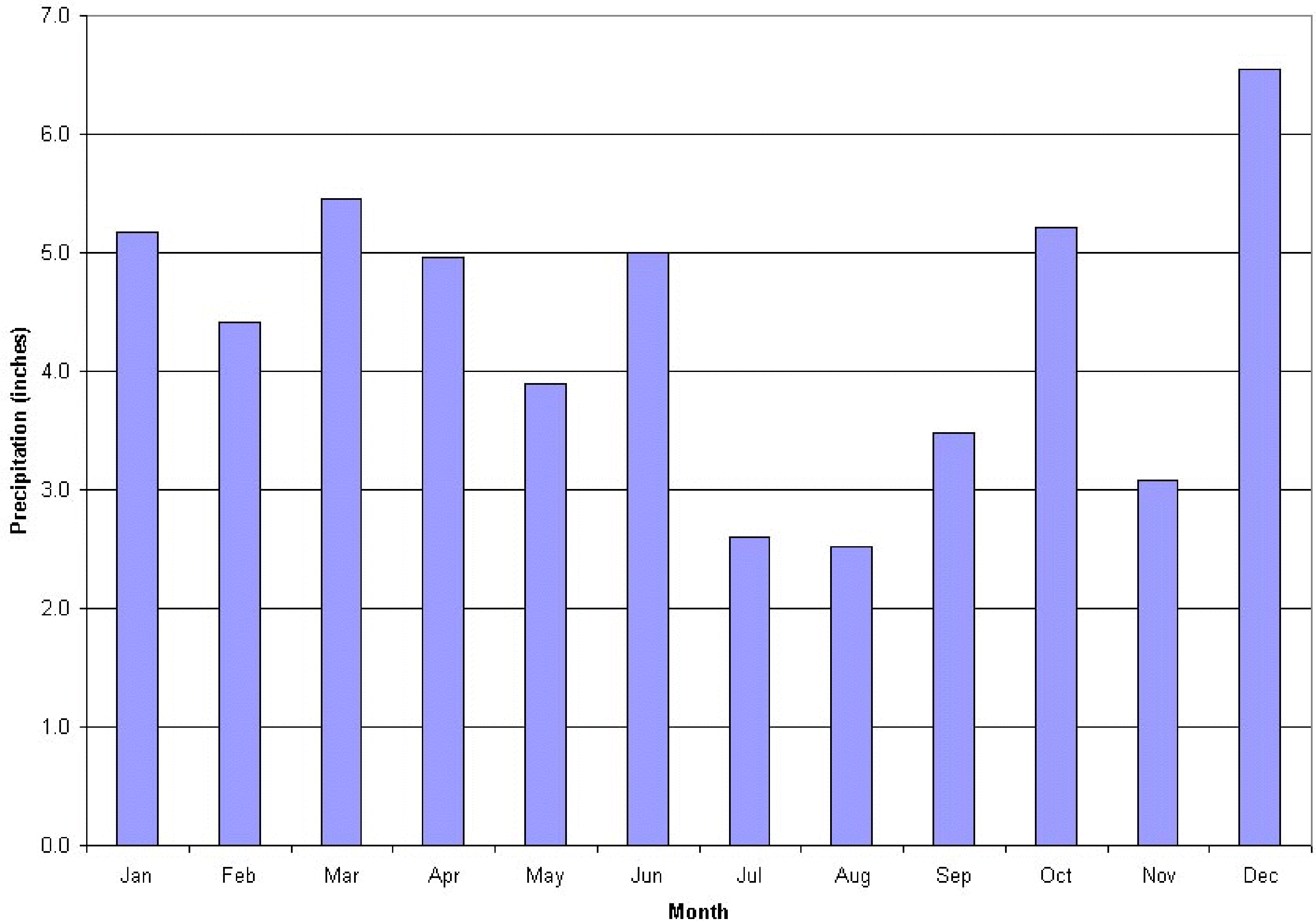


Figure 2.3. Mean monthly precipitation for HUC 11110206.

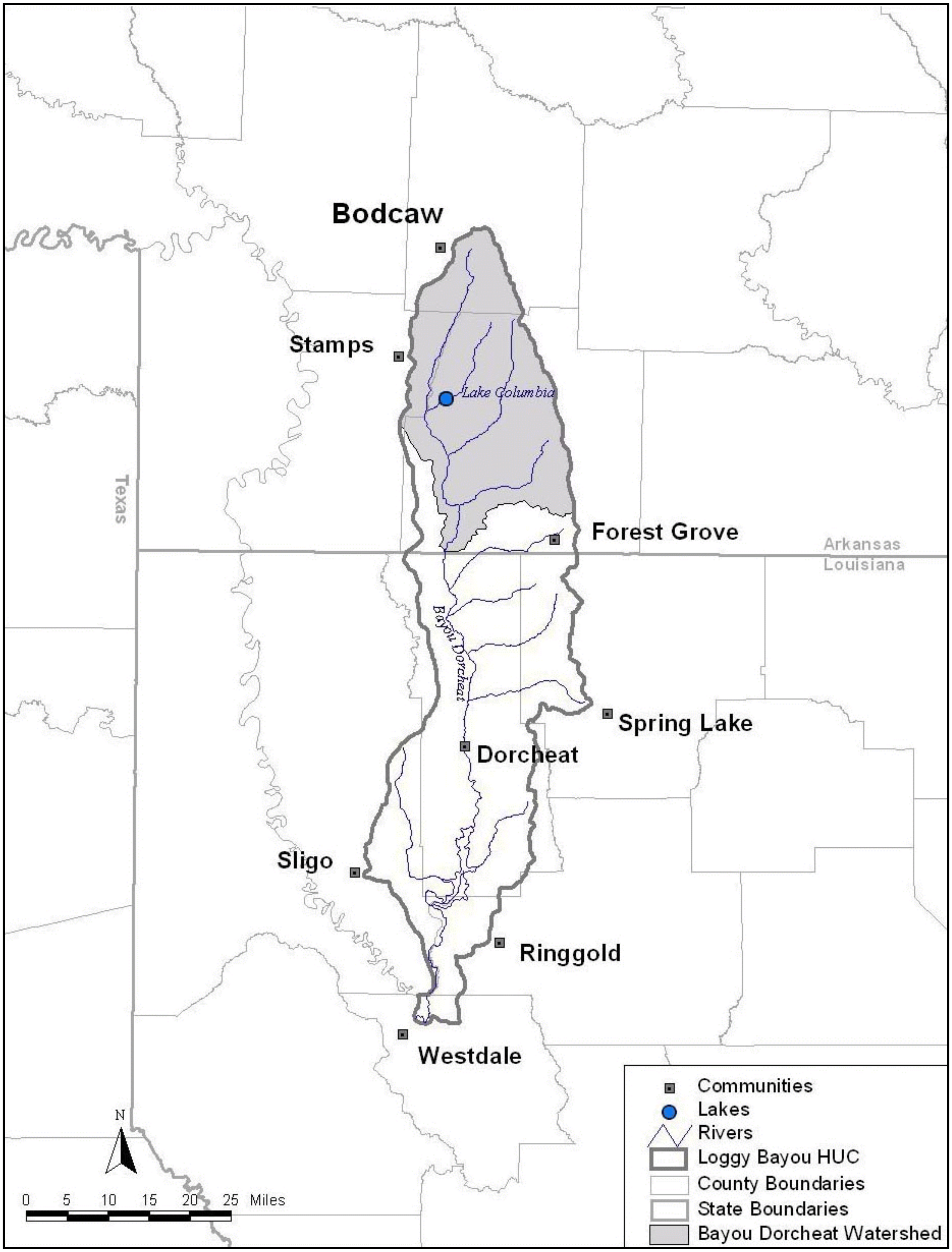


Figure 2.4. Loggy Bayou HUC 11140203.

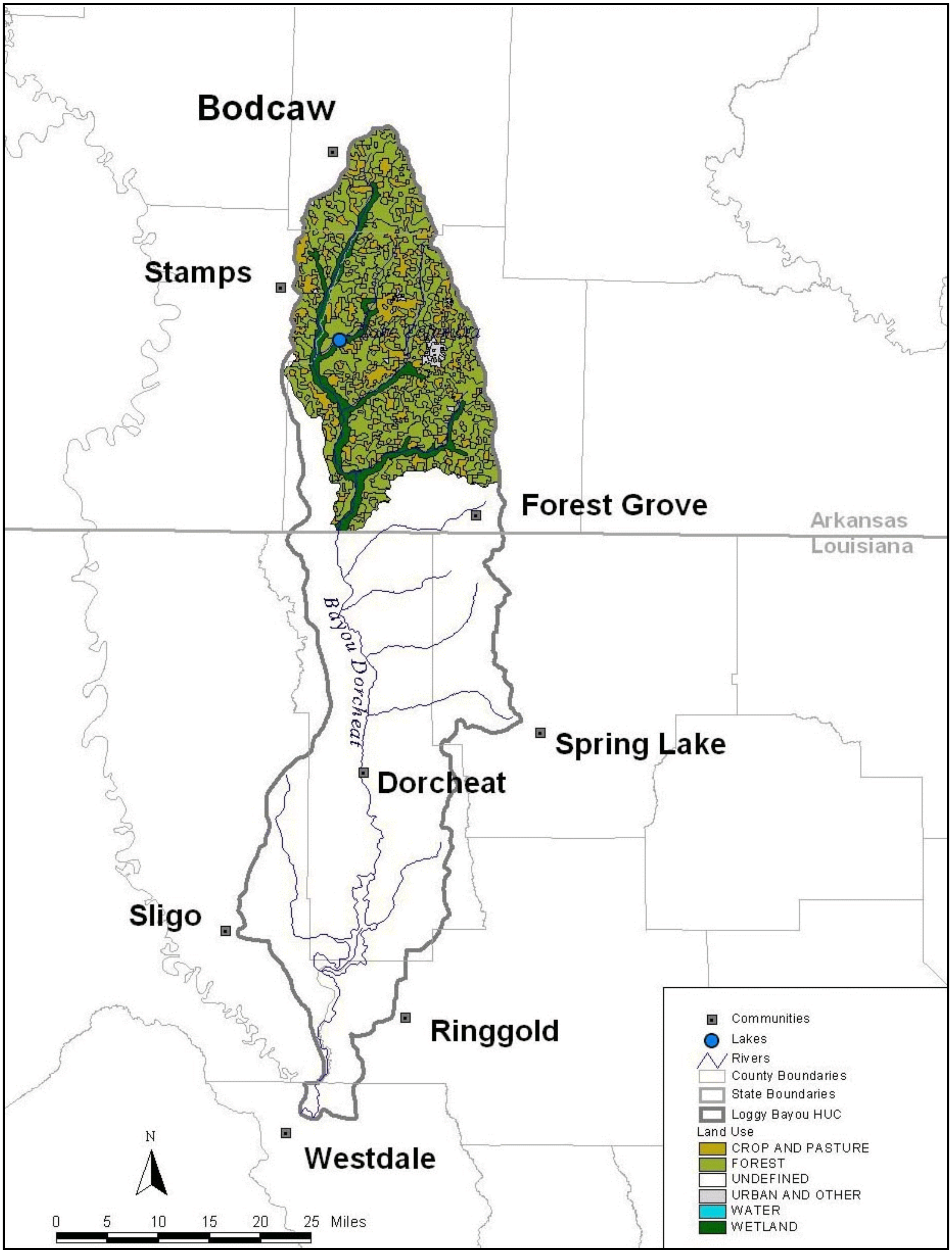


Figure 2.5. Bayou Dorcheat watershed major land use categories.

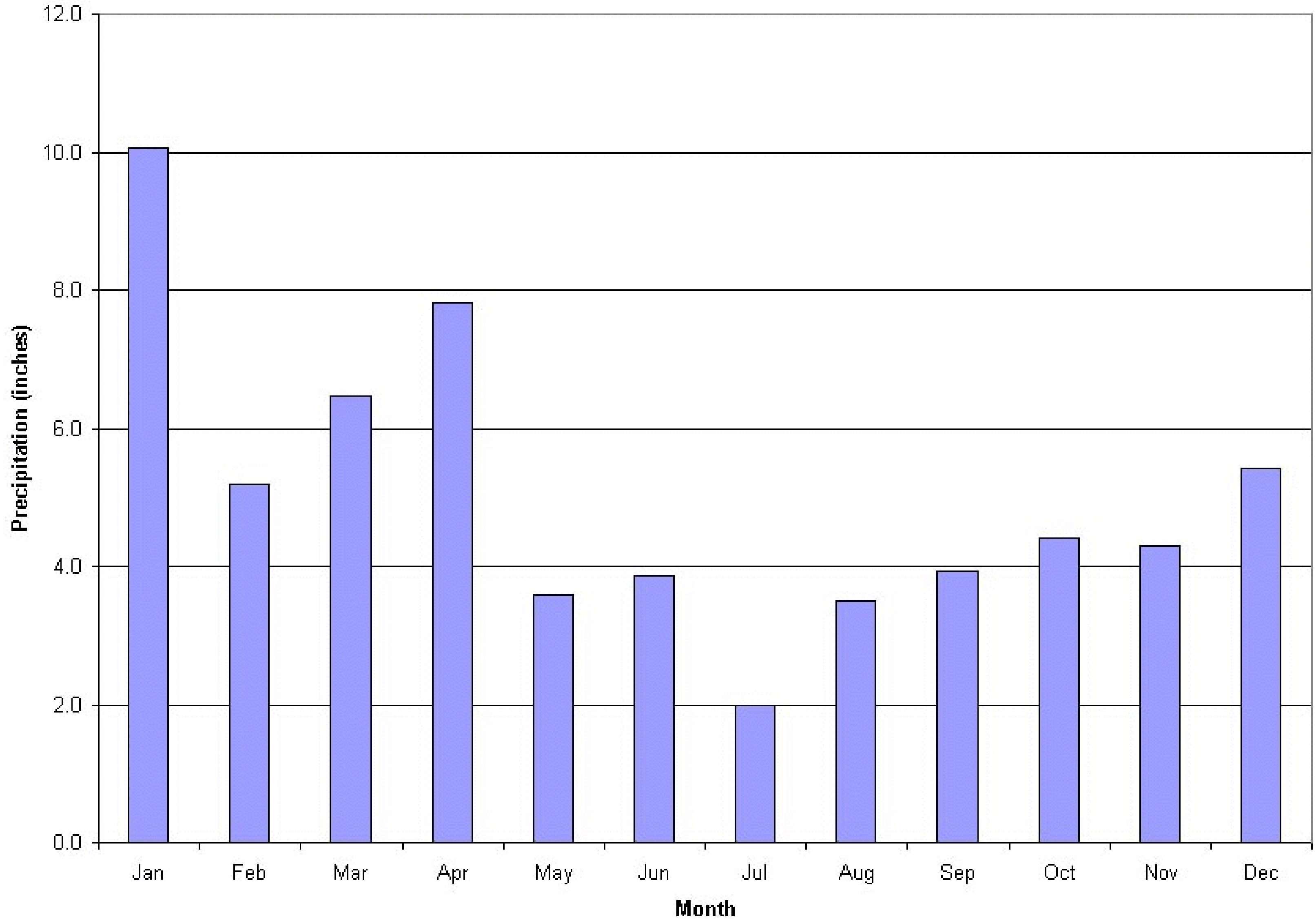


Figure 2.6. Mean monthly precipitation for HUC 11140203.

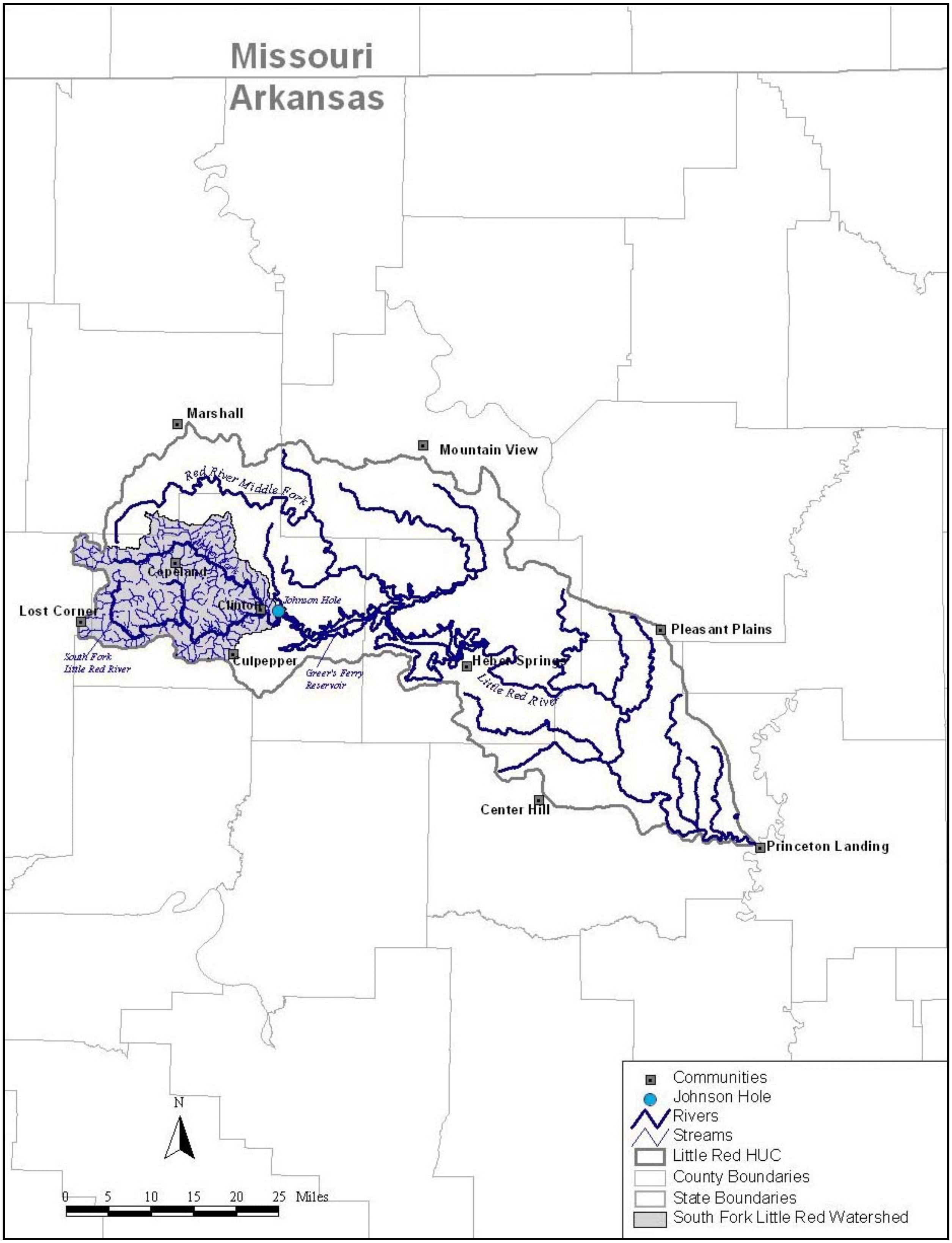


Figure 2.7. Little Red HUC 11010014.

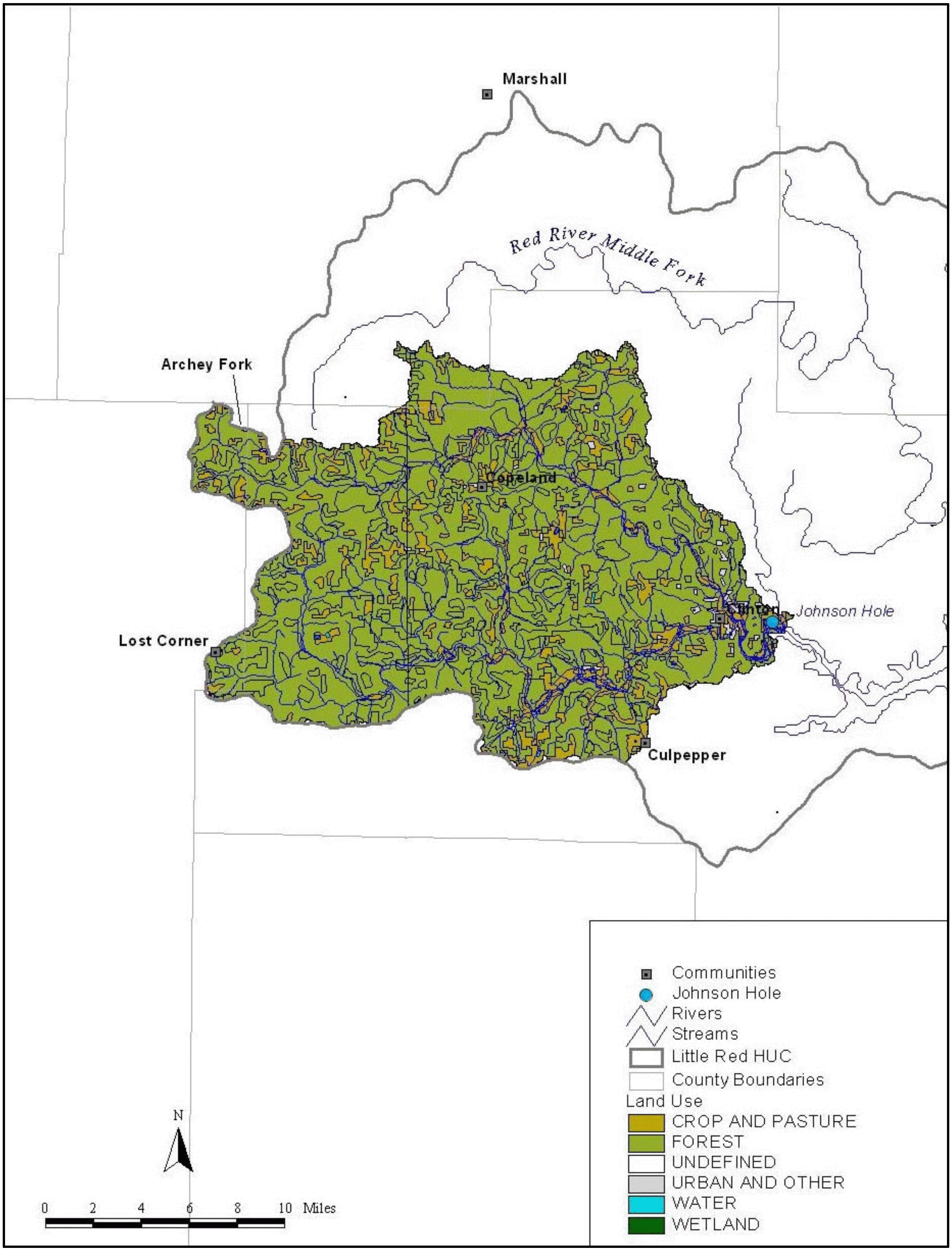


Figure 2.8. South Fork Little Red watershed major land use categories.

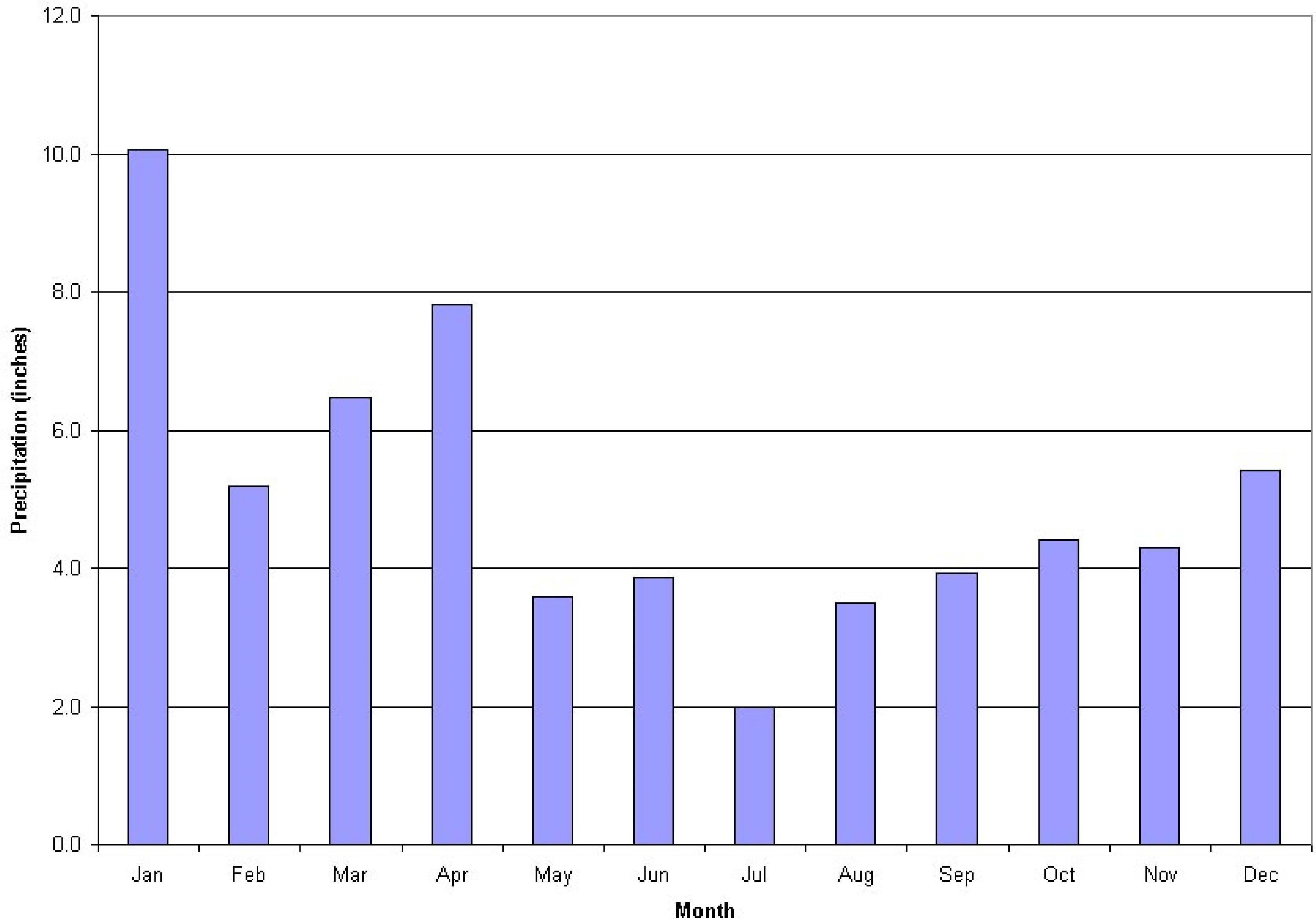


Figure 2.9. Mean monthly precipitation for HUC 11010014.

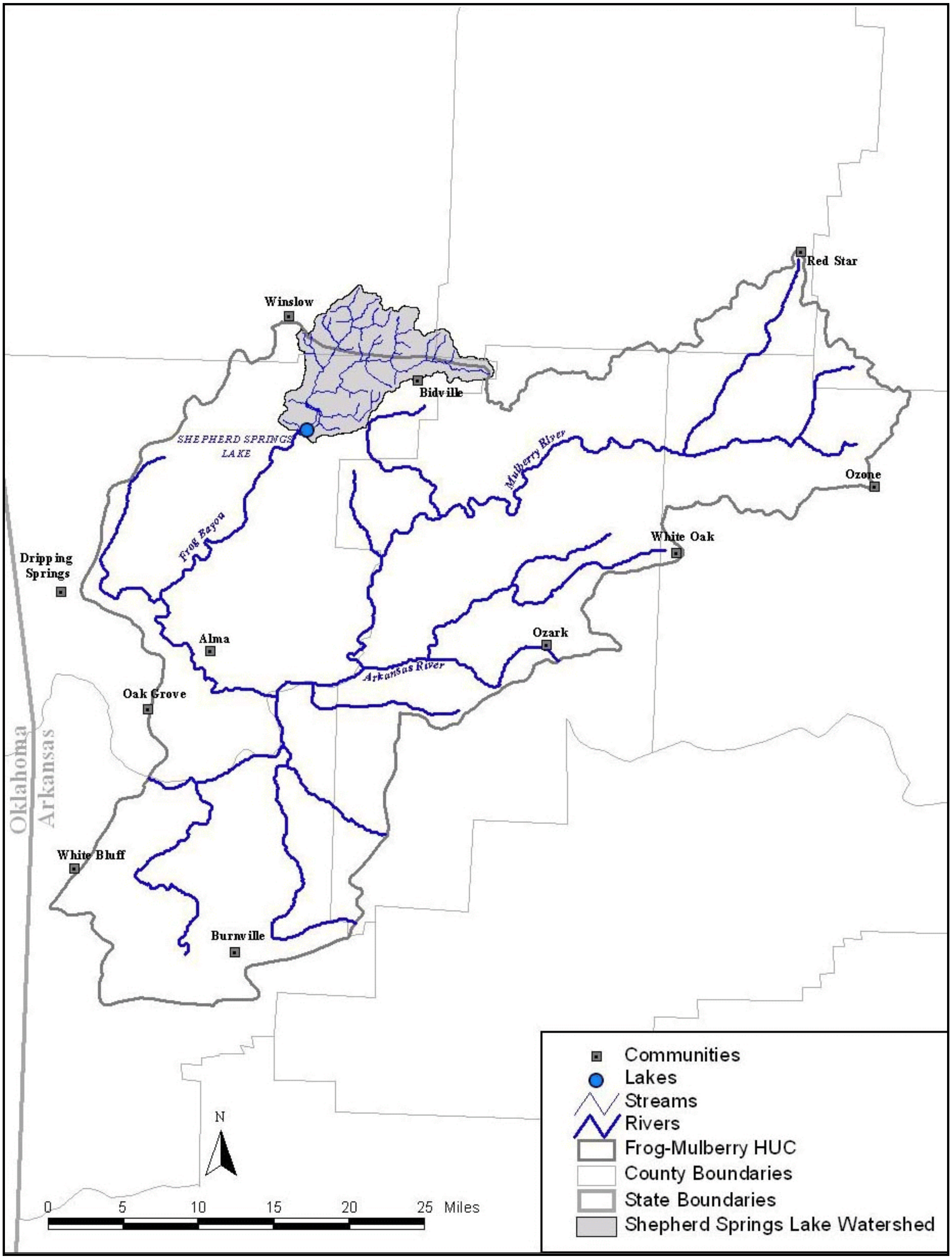


Figure 2.10. Frog-Mulberry HUC 11110201.

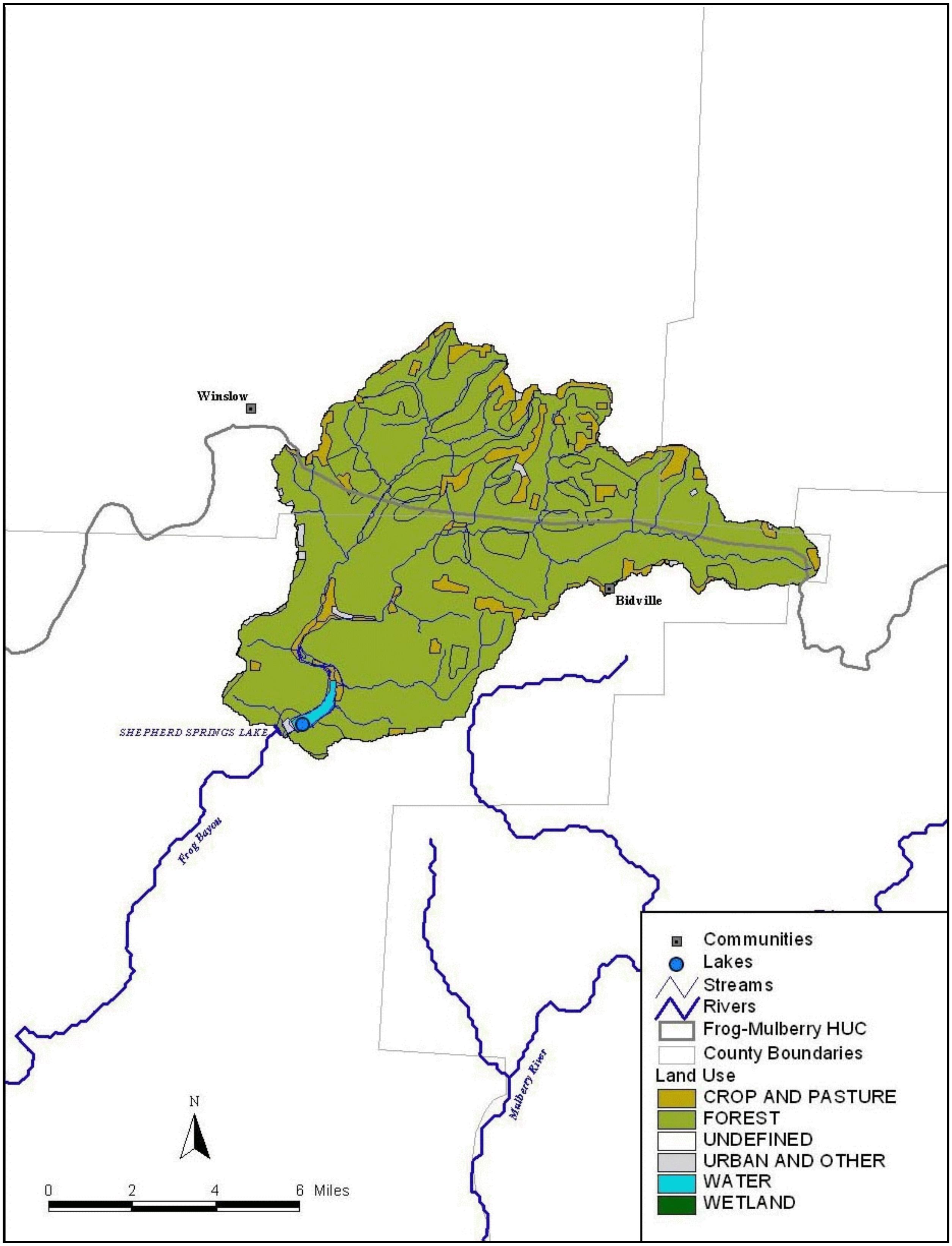


Figure 2.11. Shepherd Springs Lake watershed major land use categories.

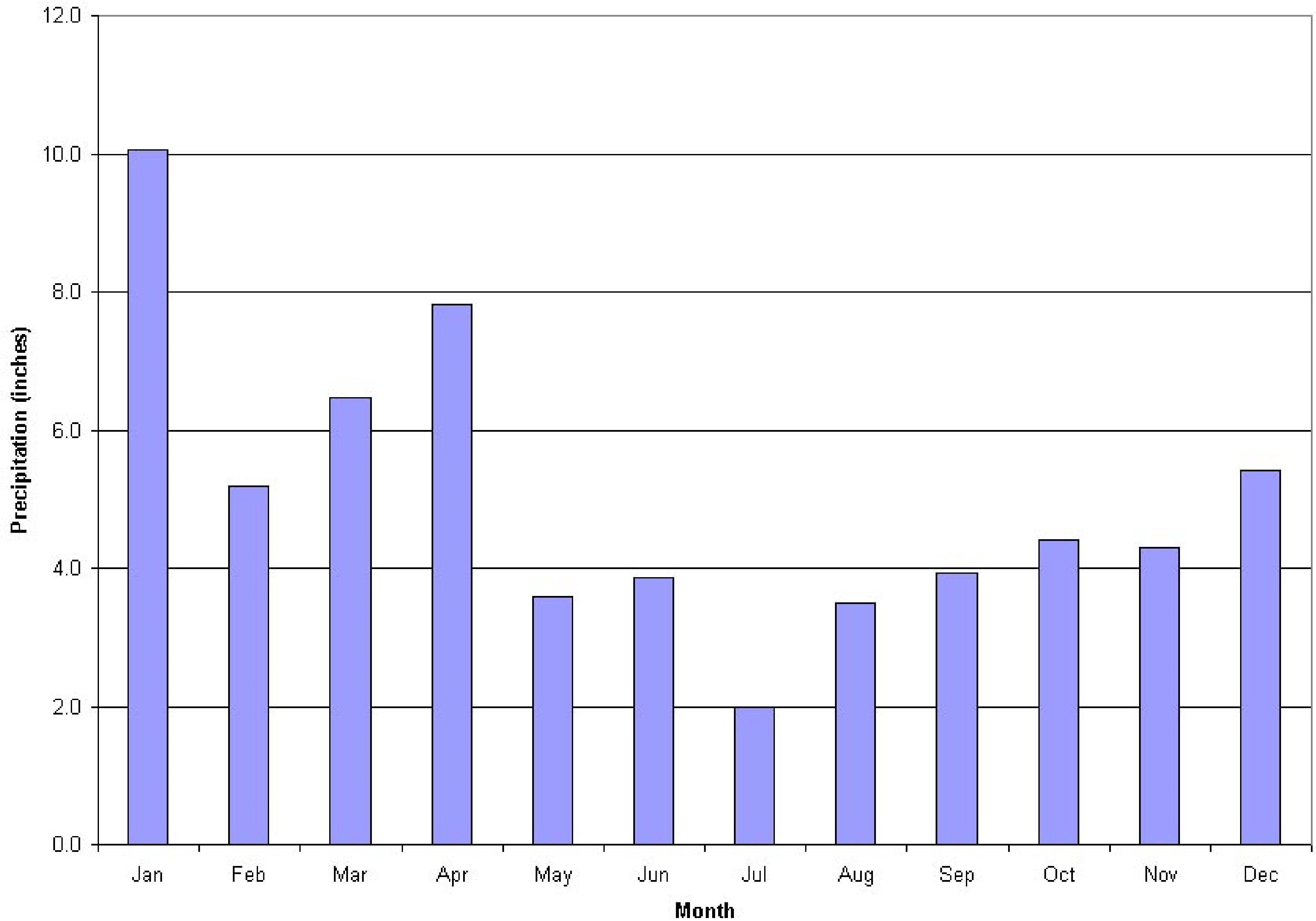


Figure 2.12. Mean monthly precipitation for HUC 11110201.

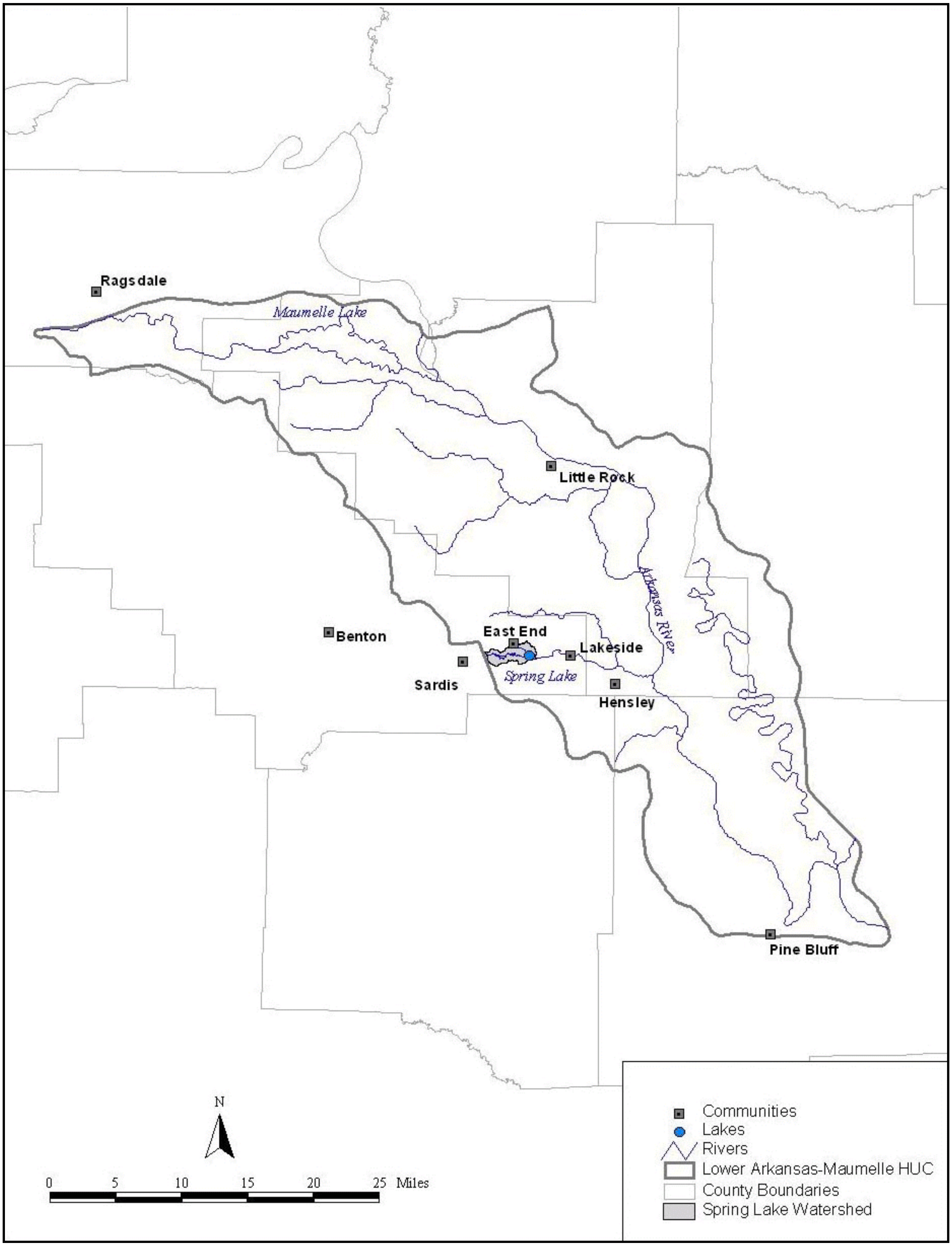


Figure 2.13. Lower Arkansas - Maumelle, HUC 11110207.

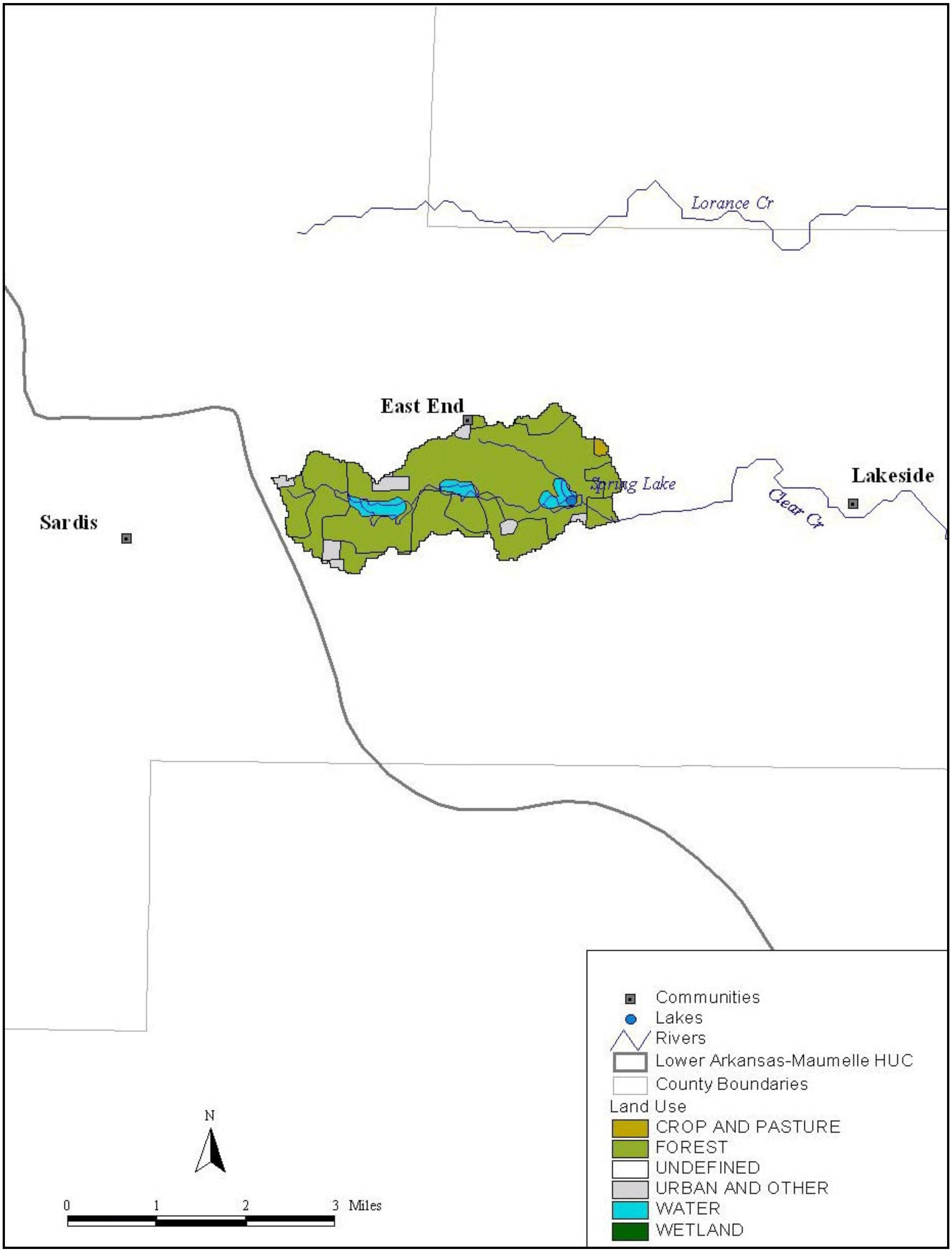


Figure 2.14. Spring Lake watershed major land use categories.

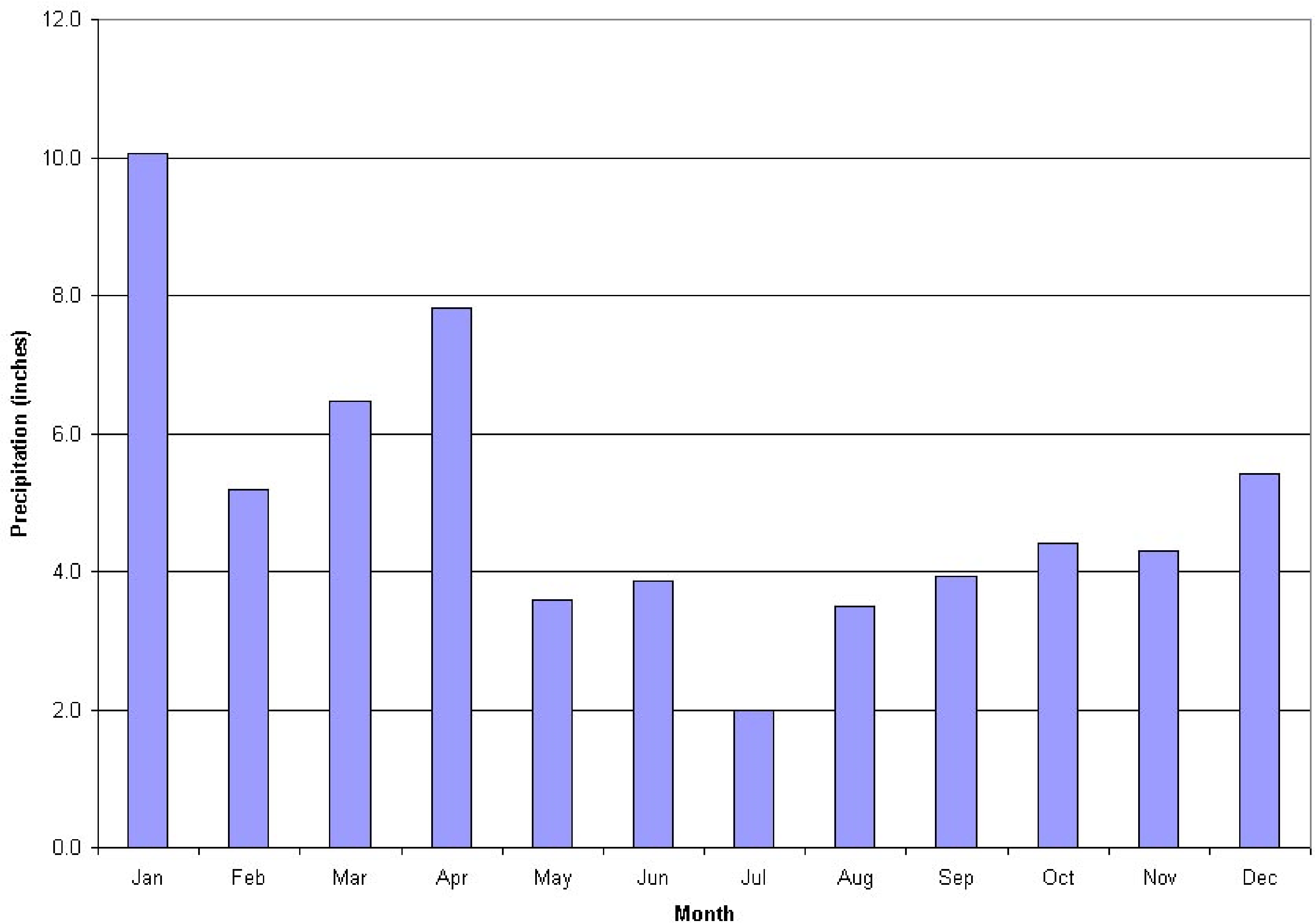


Figure 2.15. Mean monthly precipitation for HUC 11110207.

Figure 2.16. Lower Arkansas-Maumelle HUC 11110207 and Upper Saline HUC 08040203.

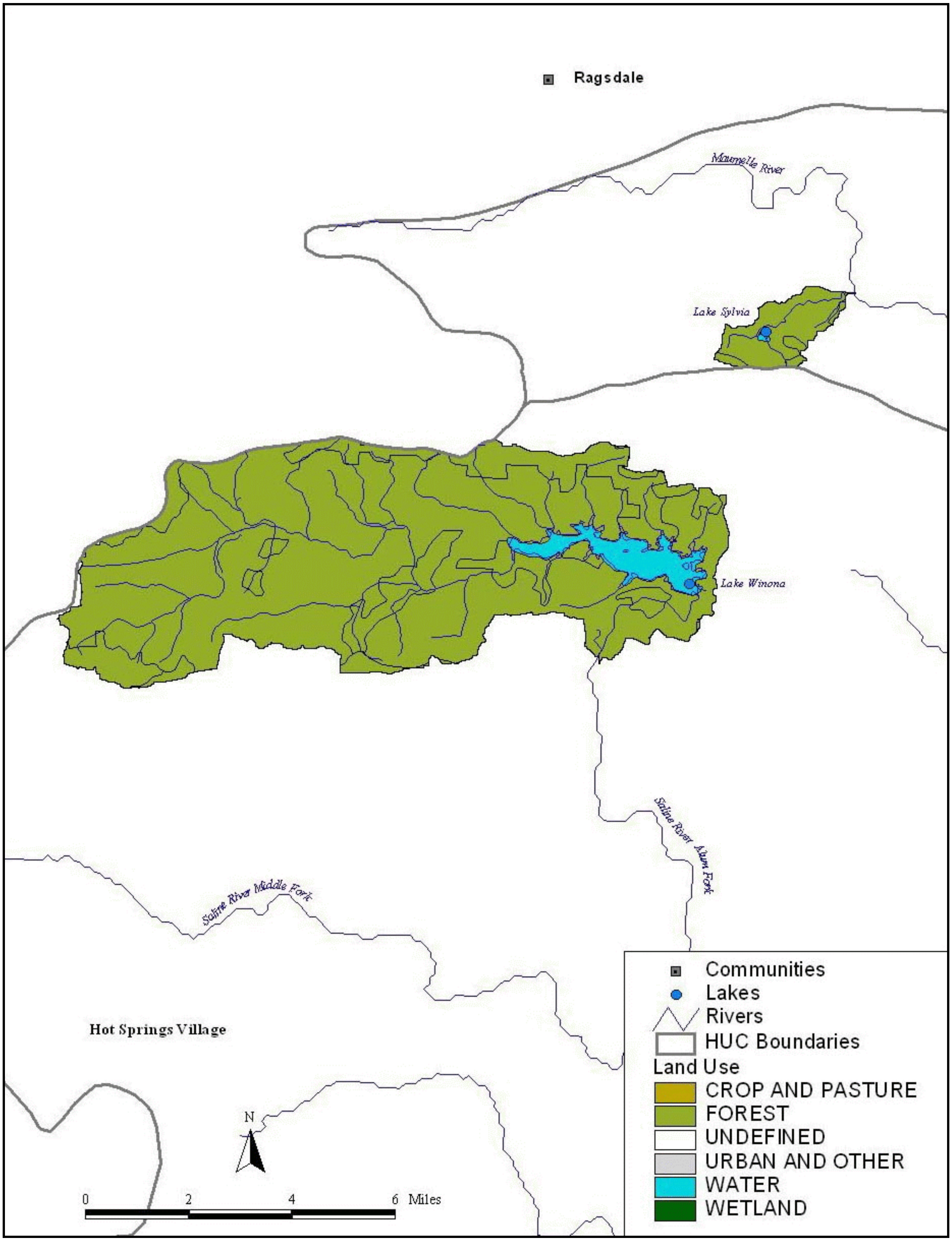


Figure 2.17. Lake Winona and Lake Sylvia watersheds major land use categories.

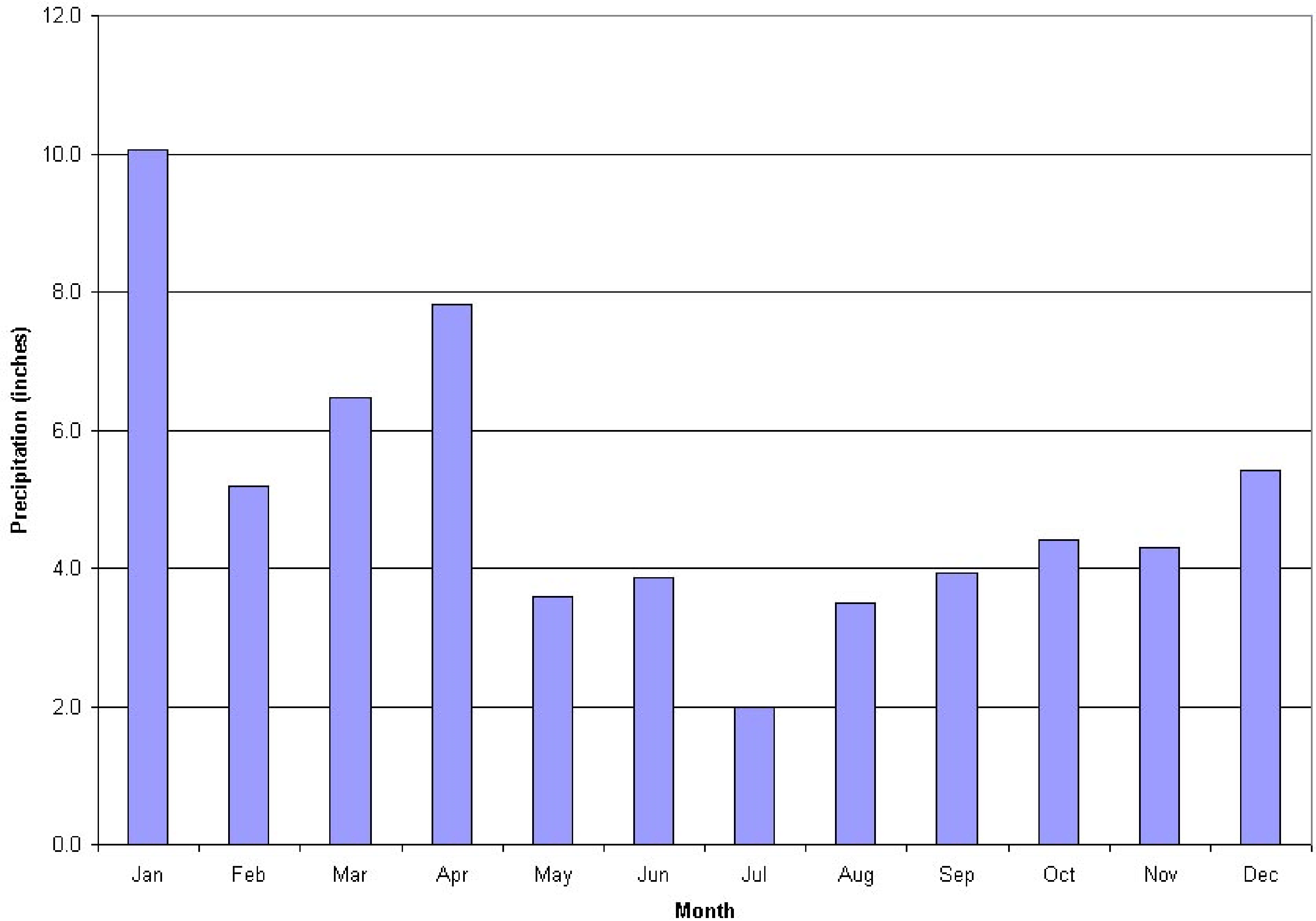


Figure 2.18. Mean monthly precipitation for HUC 11110207 and HUC 08040203.

3.0 WATER QUALITY STANDARDS AND EXISTING WATER QUALITY CONDITIONS

3.1 Water Quality Standards

The State of Arkansas has developed water quality standards for waters of the State (ADEQ 1998). The standards are defined according to ecoregions and designated uses of the waterbodies. The mercury water quality standard for Arkansas waters for all ecoregions is 0.012 μg/L, expressed as total recoverable mercury. Although this water quality standard is to protect aquatic life, it was developed to protect humans from consuming aquatic life contaminated by mercury. There is no correction factor for hardness or other constituent concentrations. The narrative standard for toxic substances in Section 2.508 (Regulation No. 2, ADPCE 1998) is “Toxic substances shall not be present in receiving waters, after mixing, in such quantities as to be toxic to human, animal, plant or aquatic life or to interfere with the normal propagation, growth and survival of the indigenous aquatic biota.”

3.2 Existing Water Quality Conditions

There have been no recorded exceedances of the mercury water quality standard in the waterbodies being addressed in this TMDL study. The analytical procedures used previously had a detection limit of 0.2 μg/L and all samples were less than the detection limit.

However, there are fish consumption advisories for mercury contamination in the waterbodies being addressed in this TMDL study. The fish consumption Action Level in Arkansas is based on the previous FDA guideline of 1 mg/kg. The location of these fish consumption advisories and the highest average composite bass fish mercury concentrations for the stations sampled in these waterbodies are discussed in Section 3.3.

EPA recently promulgated a criterion for methylmercury in fish tissue. The EPA criterion is 0.3 mg/kg of methylmercury in fish tisue (EPA 2001). The State of Arkansas will need to consider adopting this criterion as part of its triennial review.

This TMDL study uses fish tissue monitoring data as a means to determine whether the “fishable” use is being met, and the reductions needed to achieve the designated use. The "fishable" use is not attained if: (1) the fish and wildlife propagation is impaired and/or (2) if there is a significant human health risk from consuming fish and shellfish resources. The waterbodies included in this TMDL study were listed in the 1998 303(d) List based on elevated fish tissue mercury concentrations, and/or are in violation of narrative standards for toxic substances. To achieve the designated use, the fish tissue mercury concentration of 1.0 mg/kg should not be exceeded. Therefore, the target tissue mercury level for all fish species in this TMDL study will be 0.8 mg/kg. This incorporates a 20% Margin of Safety in the analyses (see Section 5.0).

Water quality data for sulfate, total organic carbon (TOC), and pH were obtained from the EPA STORET system. The stations, agency, HUC, and period of record (POR) for the sulfate, TOC, and pH data used for this study are listed in Table 3.1. These water quality data are summarized in Figures 3.1 through 3.9. These three constituents have been demonstrated to be correlated with fish mercury concentrations and can affect the bioaccumulation and bioavailability of mercury for methylation and subsequent uptake of methylmercury through the food chain (Armstrong et al. 1995, EPA 1998). Areas with moderate sulfate and TOC concentrations and lower pH values provide an environment conducive to microorganisms that methylate mercury (Armstrong et al. 1995). These conditions likely contribute to the elevated fish mercury concentrations in Bayou Dorcheat and possibly other areas for which measurements of these parameters are not available. In addition, wetland ecosystems have conditions that are particularly suited to organisms that methylate mercury (Rudd 1995).

3.3 Fish Sampling and Analysis

ADEQ followed the sampling protocols recommended in *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories,* Vol 1 (EPA 1995). Fish were collected from 1993 through 1999 in rivers and lakes within the watersheds (Armstrong et al. 1995). The maximum and average composite fish mercury concentrations for largemouth bass are listed in Table 3.2 and the maximum values shown on Figures 3.10 through 3.15. Additional fish mercury concentrations for largemouth bass and other species are included in Appendix D.

Table 3.1. Water quality monitoring stations, agencies, HUC, and POR.

Location	ID	Station	Agency	HUC	POR
Fourche La Fave River below Cedar Creek confluence	050283	ARK52B	ADEQ	11110206	2/93-6/96
Fourche La Fave River near Gravelly	050131	ARK37	ADEQ	11110206	7/93-3/97
Fourche La Fave River near Bigelow	050130	ARK36	ADEQ	11110206	10/98-12/98
Fourche La Fave River near Nimrod, AR	0726500	---	USGS	11110206	5/90-8/95
Nimrod Lake near Nimrod, AR	07262000	---	USGS	11110206	5/90-8/95
Nimrod Lake near Carter Cove, AR	07261950	---	USGS	11110206	5/90-8/95
Nimrod Lake on Prairie Creek, AR	07261925	---	USGS	11110206	5/90-8/95
Nimrod Lakenear Wards Crossing, AR	07261910	---	USGS	11110206	5/90-8/95
Nimrod Lakeat Hwy 27 bridge, AR	07261820	---	USGS	11110206	5/90-8/95
Lake Columbia - lower	050055	LRED002A	ADEQ	11140203	7/25/94
Bayou Dorcheatat Hwy 355	05UWS079	UWBTD01	ADEQ	11140203	6/94-10/96
Bayou Dorcheatat Hwy 82 6 miles W. of Waldo	05UWS091	UWBTD02	ADEQ	11140203	6/94-9/97
Bayou Dorcheat E. of Taylor, AR	050152	RED15A	ADEQ	11140203	3/97-4/98
Bayou Dorcheat near Springhill, AR	050036	RED15	ADEQ	11140203	1/90-10/93
South Fork Little Red River at Hwy 65 at Clinton	05UWS072	UWSRR02	ADEQ	11010014	5/94-12/98
South Fork Little Red River at Hwy 95 near Scotland	05UWS074	UWSRR01	ADEQ	11010014	5/94-12/98

Table 3.2. Maximum and average fish tissue mercury concentration for largemouth bass.

This list of stations and maximum fish tissue Hg concentrations was derived from the fish tissue database provided by ADEQ. The data was compiled by FTN Associates. The stations represent fish tissue mercury concentrations in bass that were above Health Department fish consumption advisory levels.

Station	Maximum Fish Hg Concentration (mg/kg)	Average Fish Hg Concentration (mg/kg)	Mean Fish Weight (grams)	Common Name
Cove Creek Lake	2.43	1.36	490	Largemouth Bass
Bayou Dorcheat	2.06	2.06*	1420	Largemouth Bass
Dry Fork Lake	2.58	1.29	554 mm (mean length)	Largemouth Bass
Fourche La Fave River	1.24	0.89	1138	Largemouth Bass
Lake Columbia	1.61	0.85	1650	Largemouth Bass
Lake Nimrod	1.26	0.71	696	Largemouth Bass
Lake Sylvia	1.08	0.87	2125	Largemouth Bass
Lake Winona	1.48	0.76	2165	Largemouth Bass
Shepherd Springs Lake	2.69	0.82	2300	Largemouth Bass
South Fork Little Red River - Johnson Hole	2.12	1.00	394	Largemouth Bass
Spring Lake	1.05	1.05*	813	Largemouth Bass

*Only one sample available.

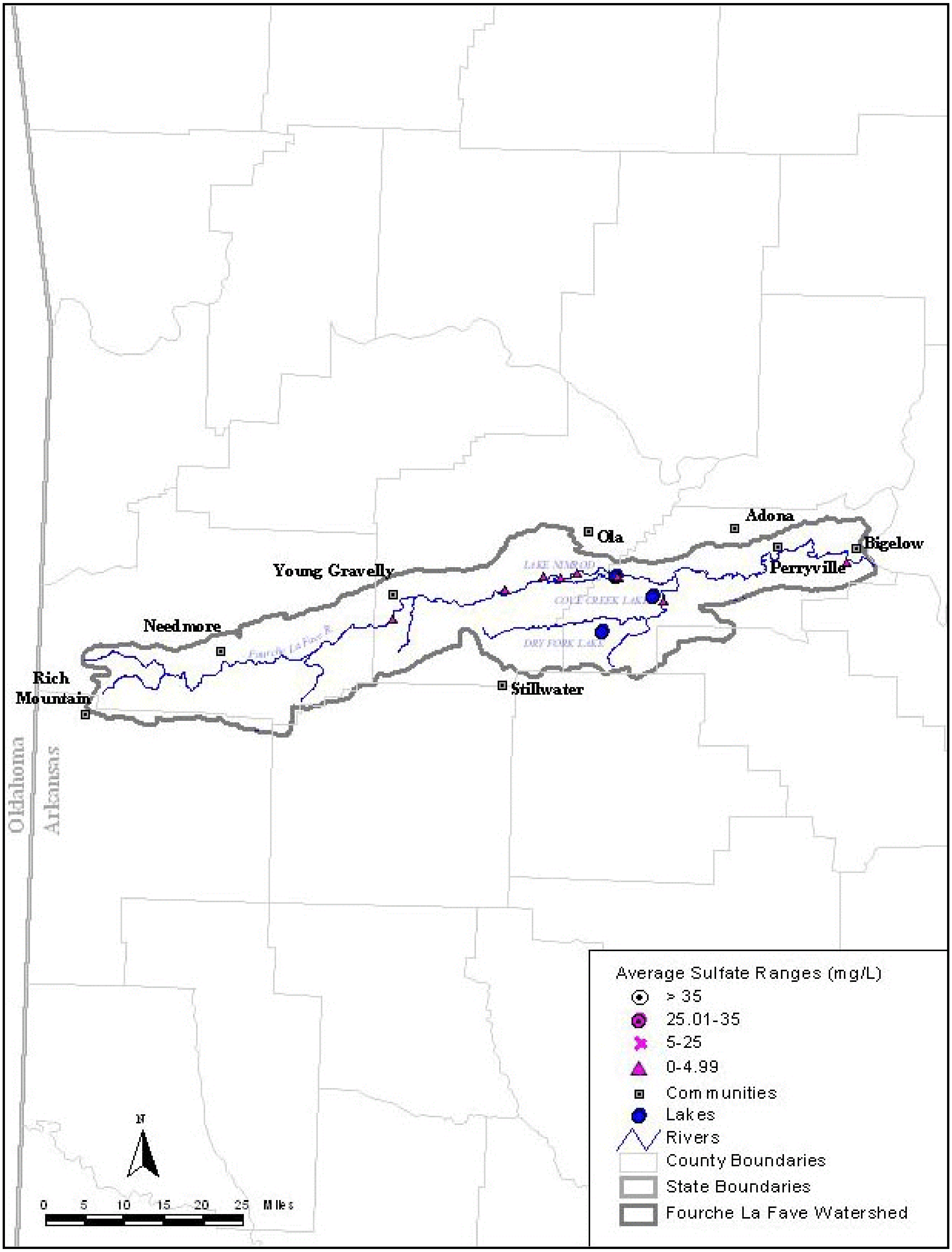


Figure 3.1. Fourche La Fave watershed sulfate ranges.

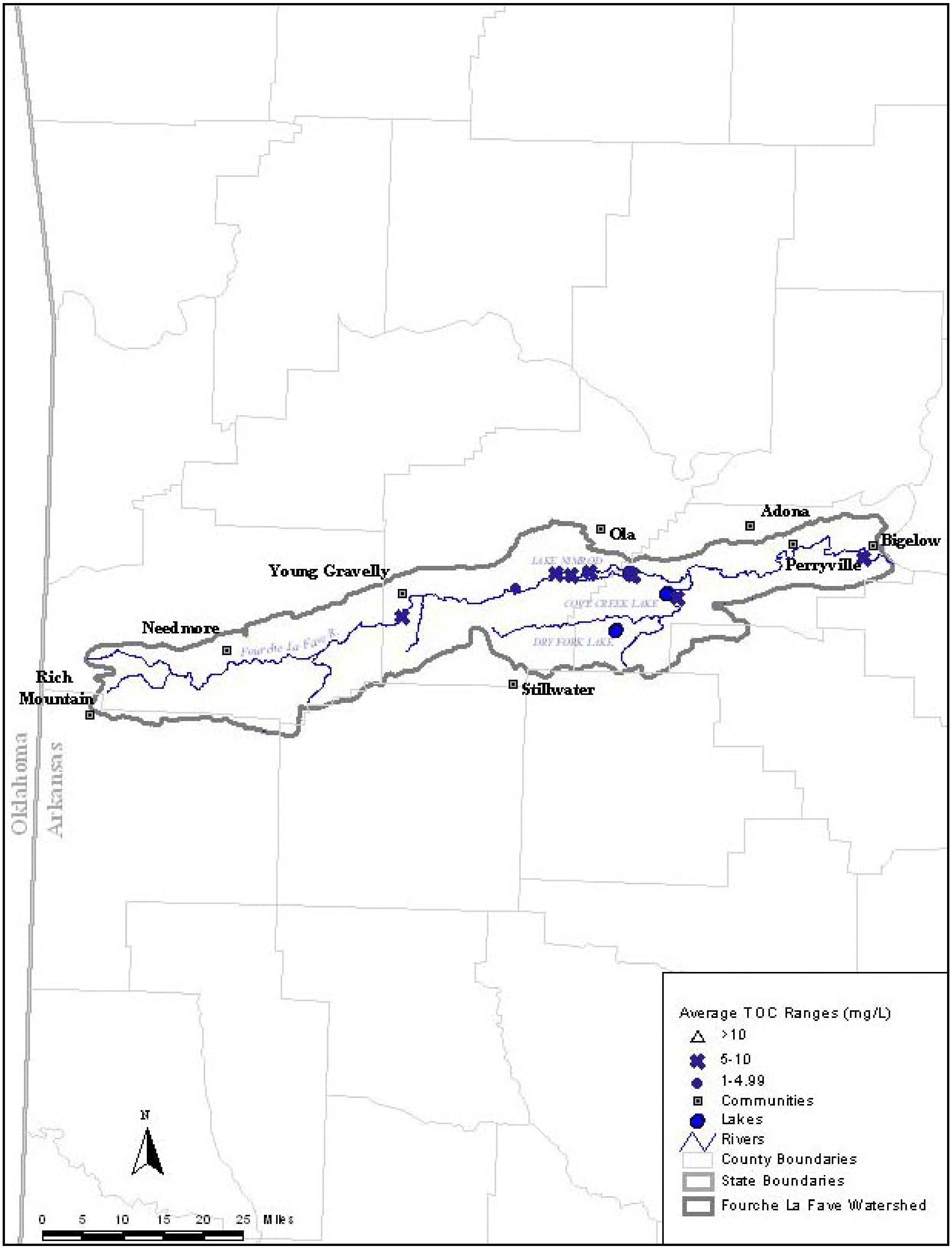


Figure 3.2. Fourche La Fave watershed TOC ranges.

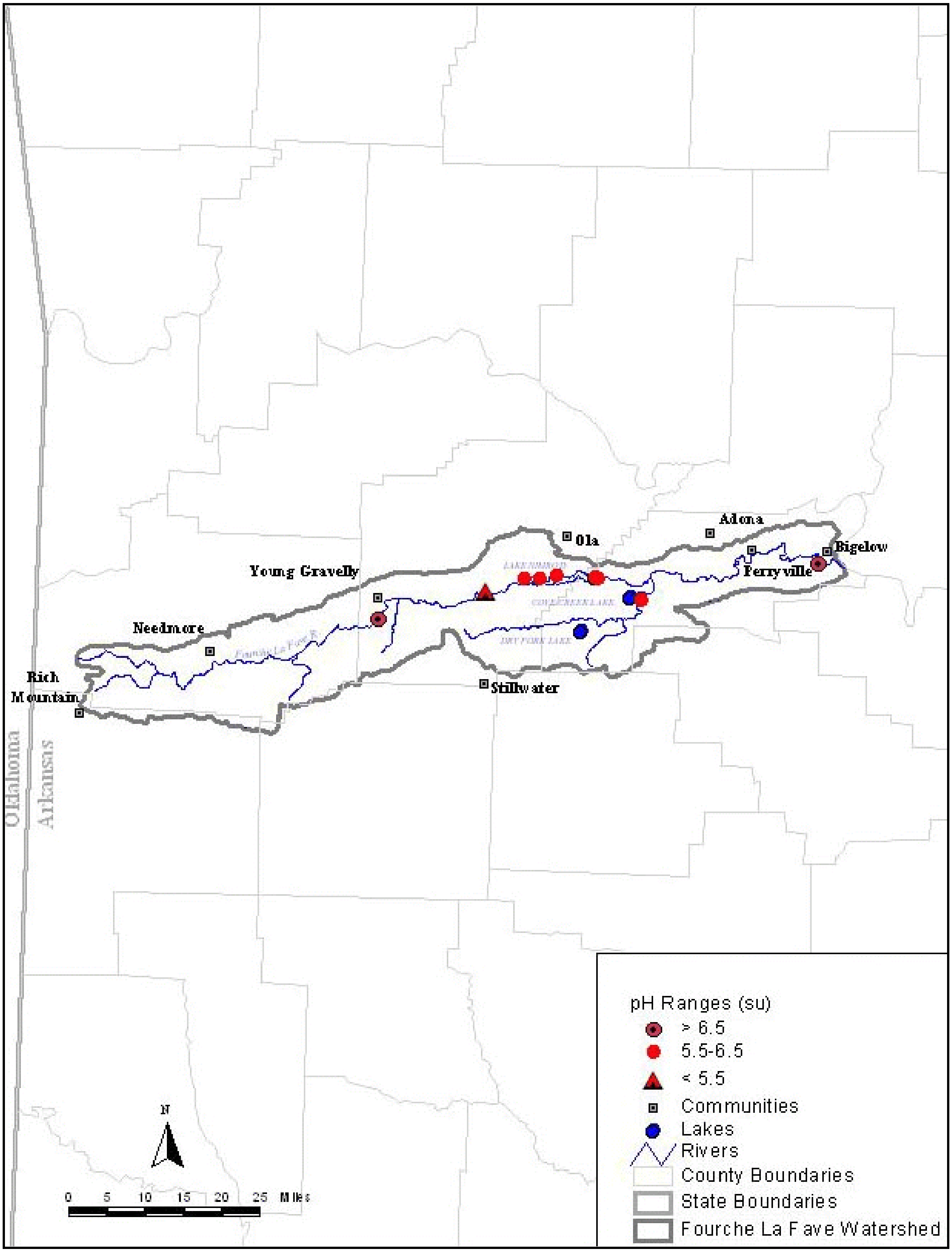


Figure 3.3. Fourche La Fave watershed pH ranges.

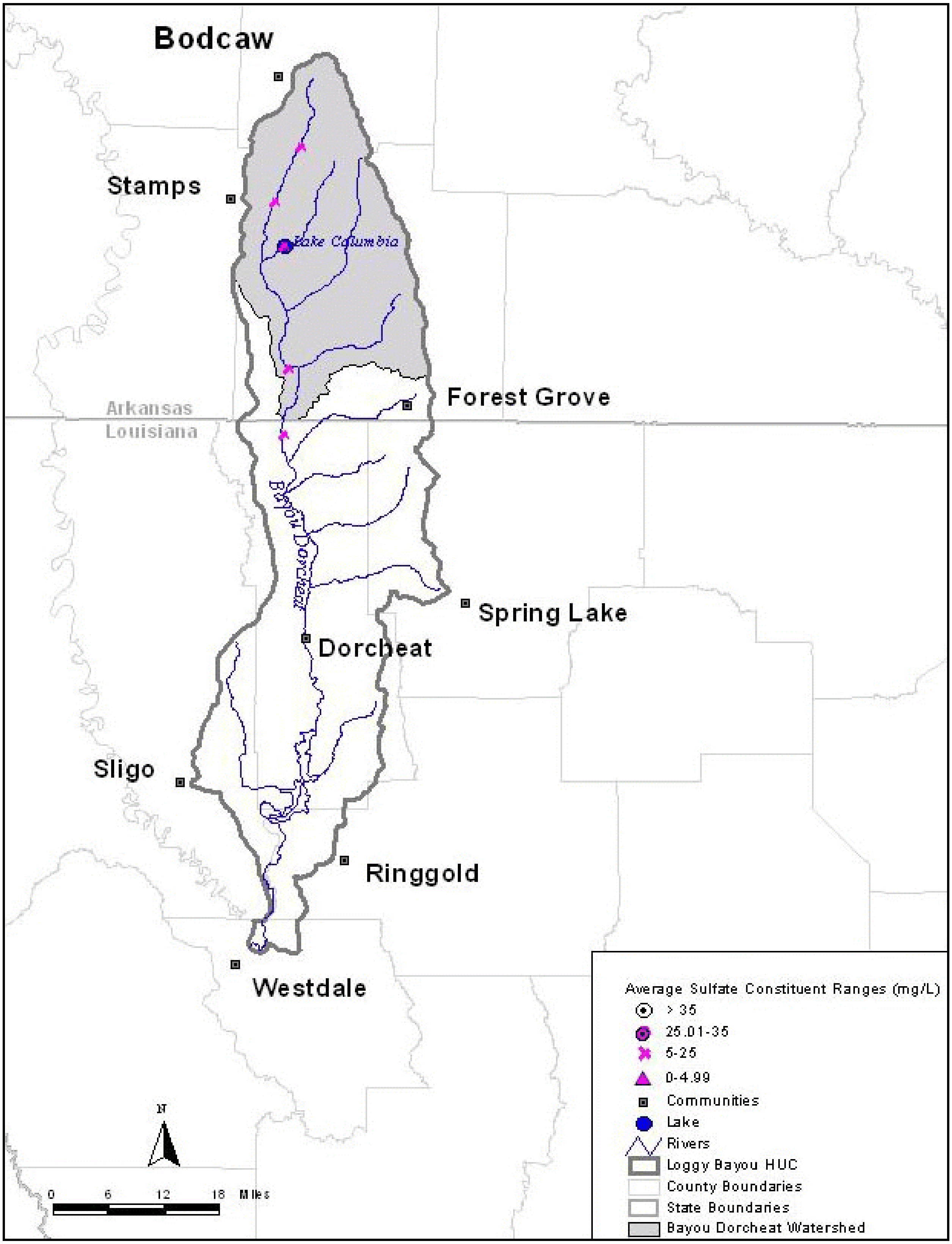


Figure 3.4. Shepherd Springs Lake watershed advisory areas and mercury levels in bass.

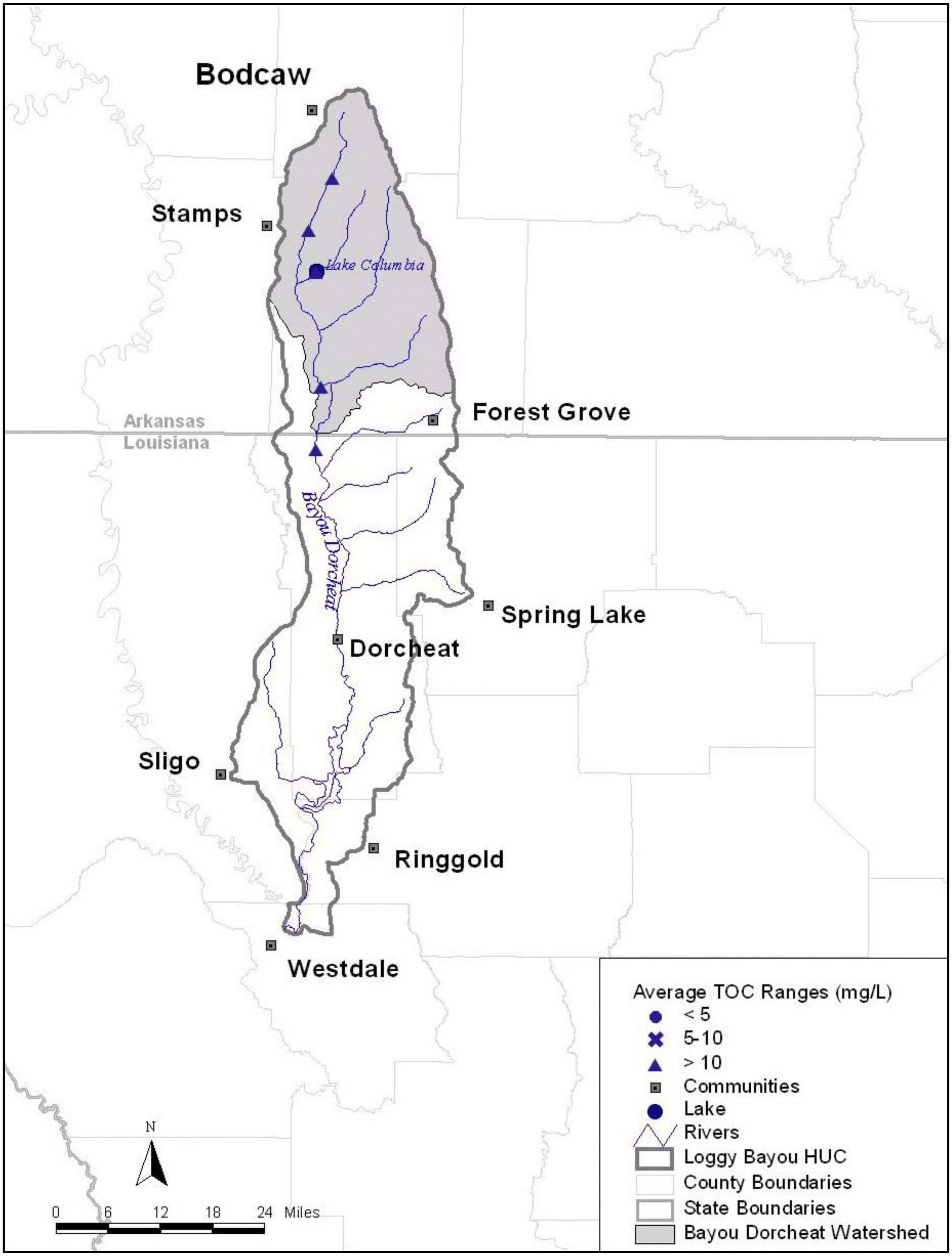


Figure 3.5. Bayou Dorcheat watershed TOC ranges.

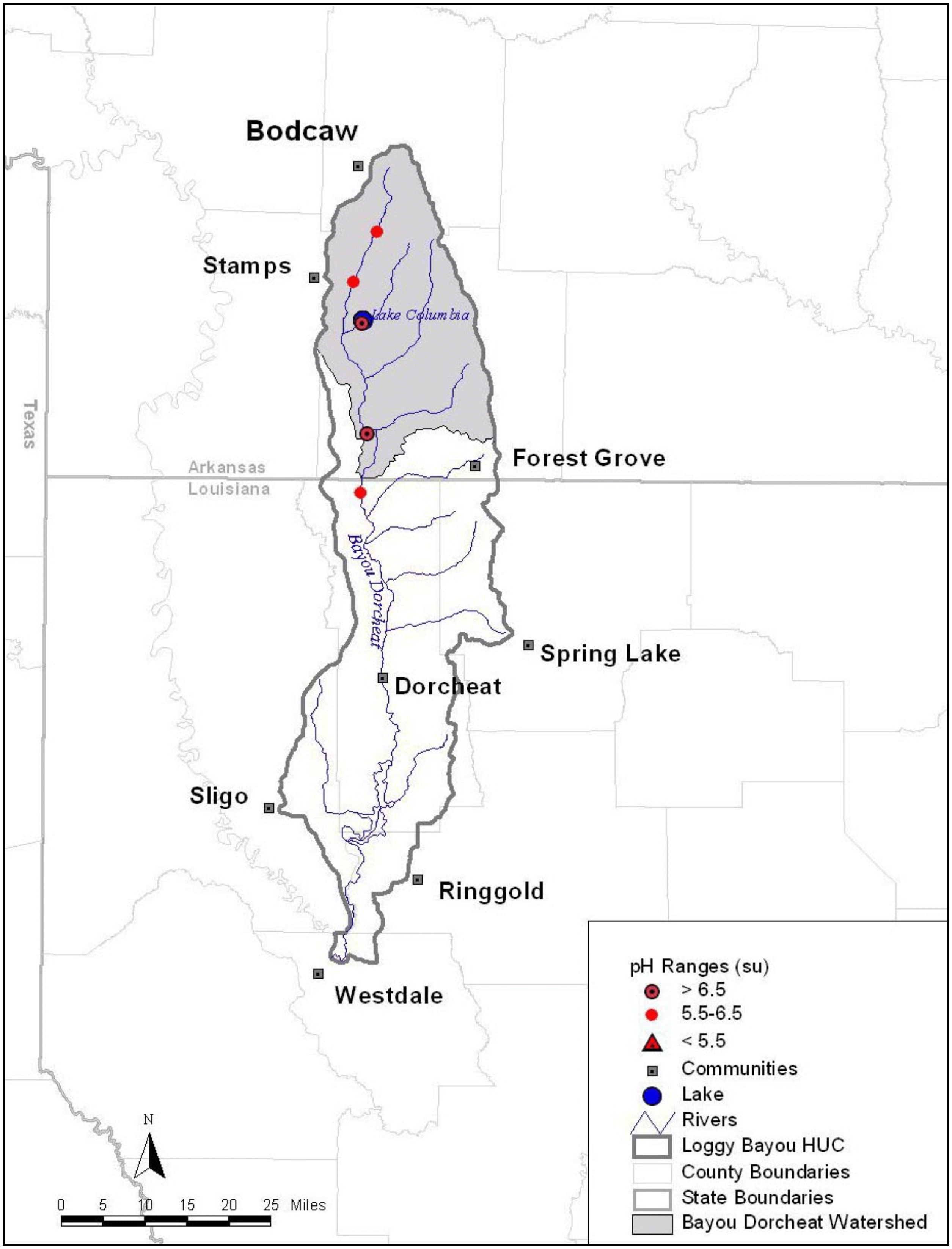


Figure 3.6. Bayou Dorcheat watershed pH ranges.

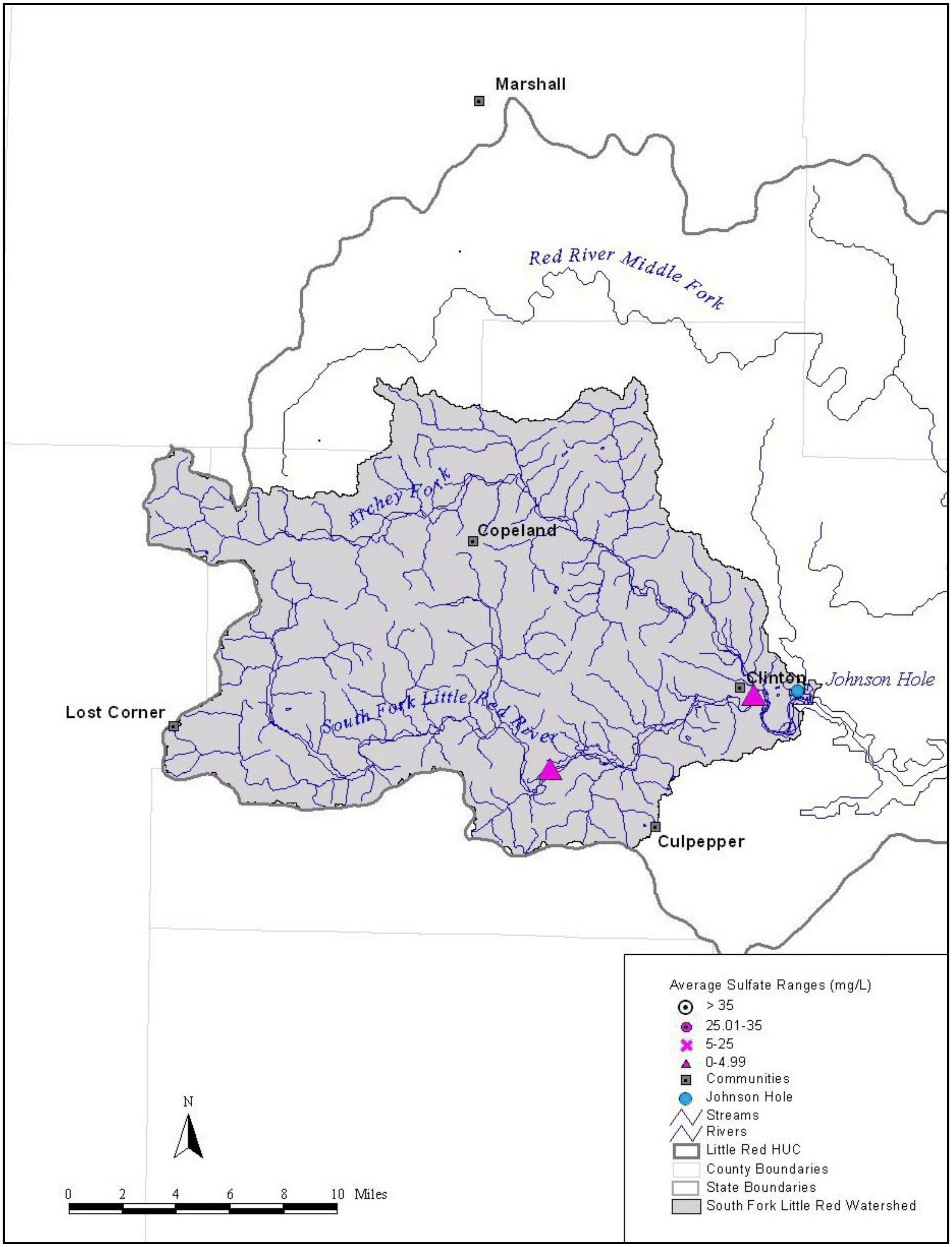


Figure 3.7. South Fork Little Red River watershed sulfate ranges.

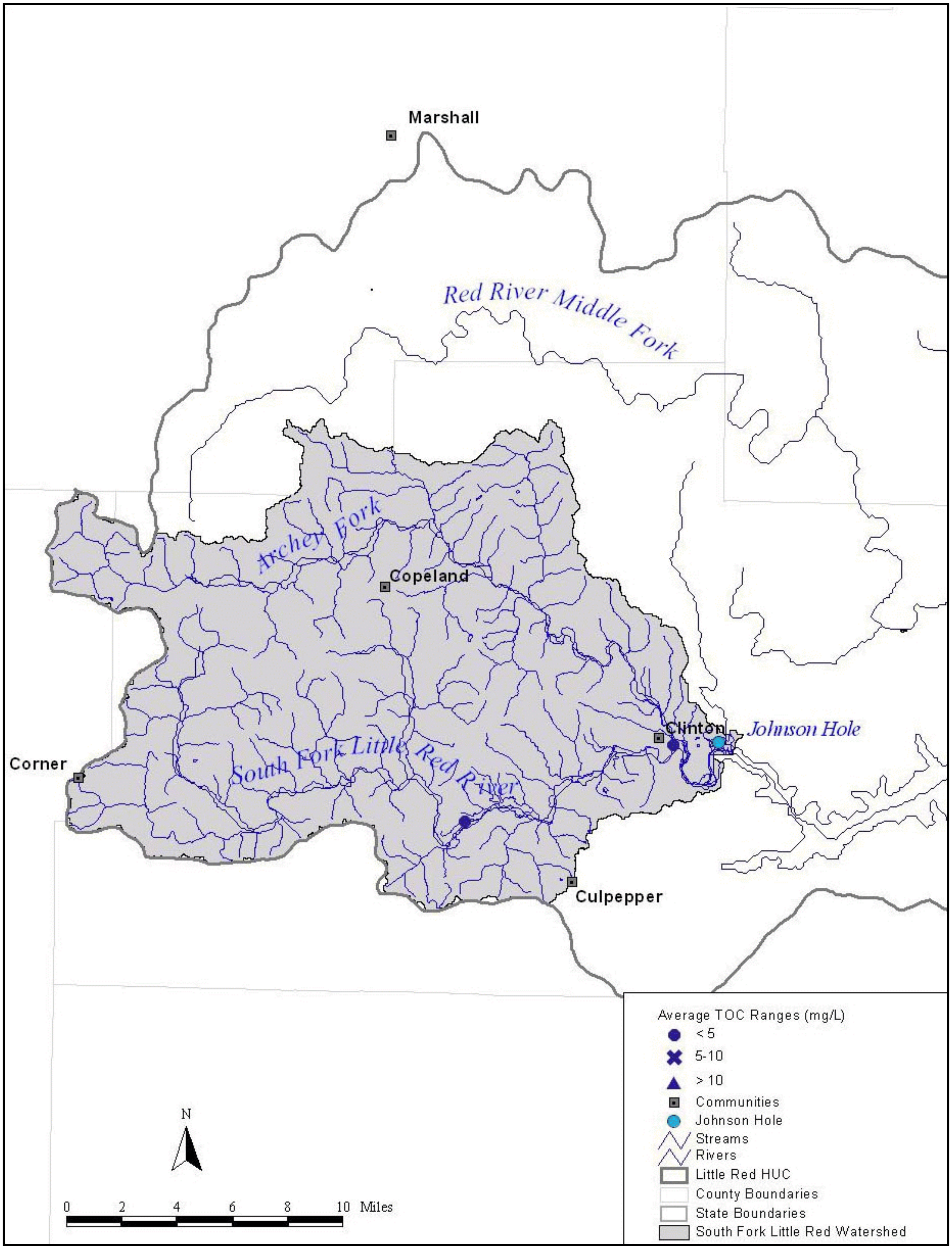


Figure 3.8. South Fork Little Red River watershed TOC ranges.

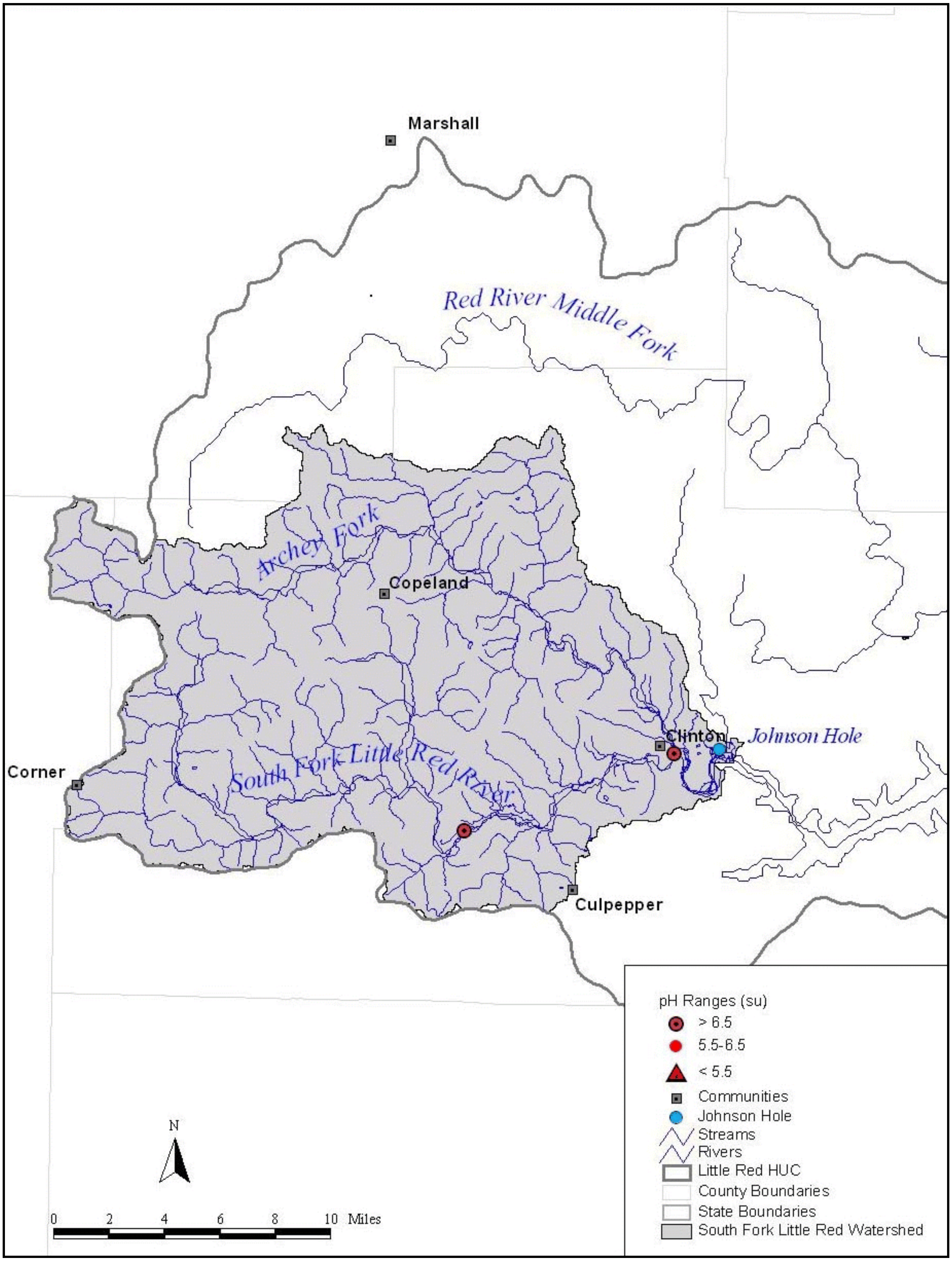


Figure 3.9. South Fork Little Red River watershed pH ranges.

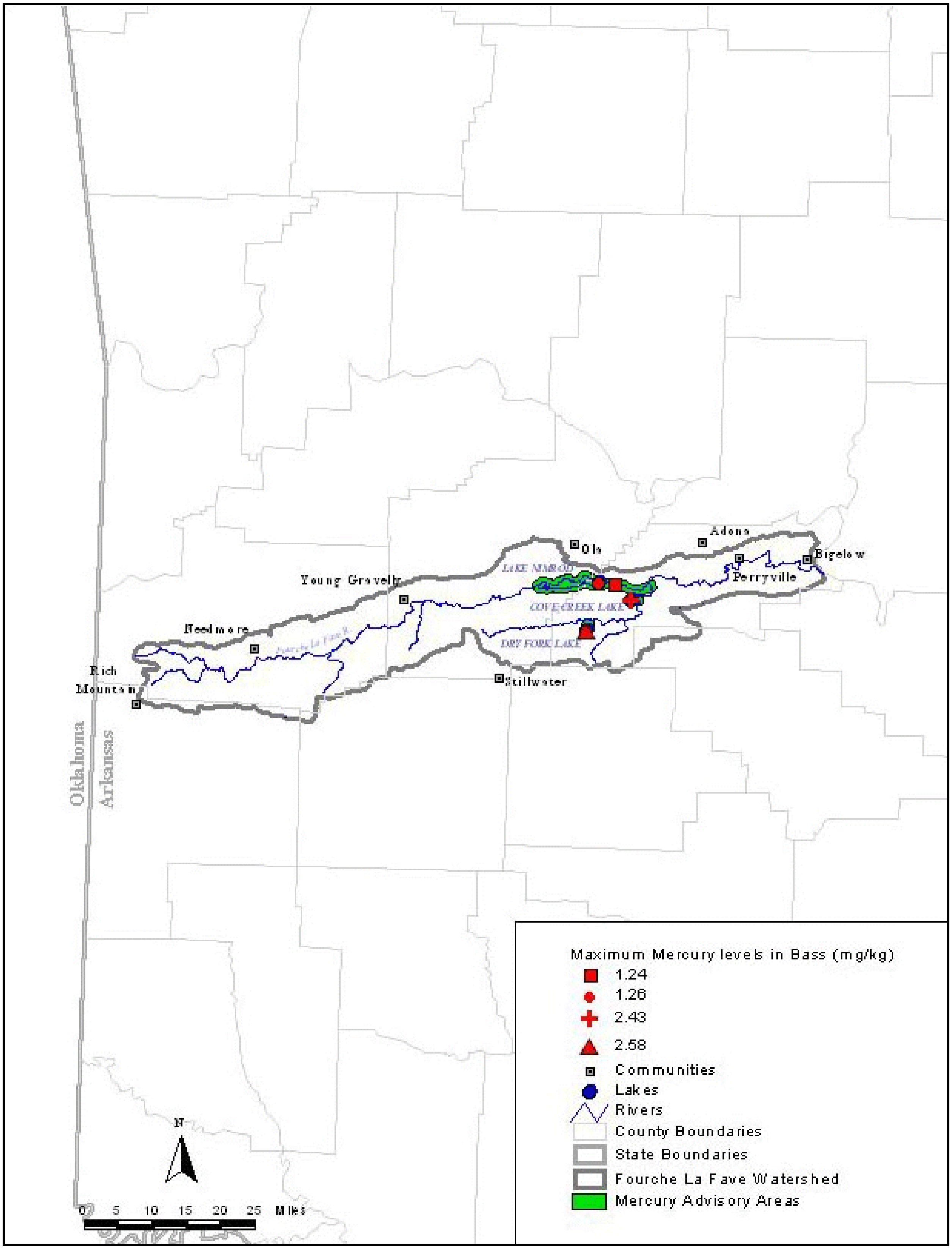


Figure 3.10. Fourche La Fave watershed advisory areas and mercury levels in bass.

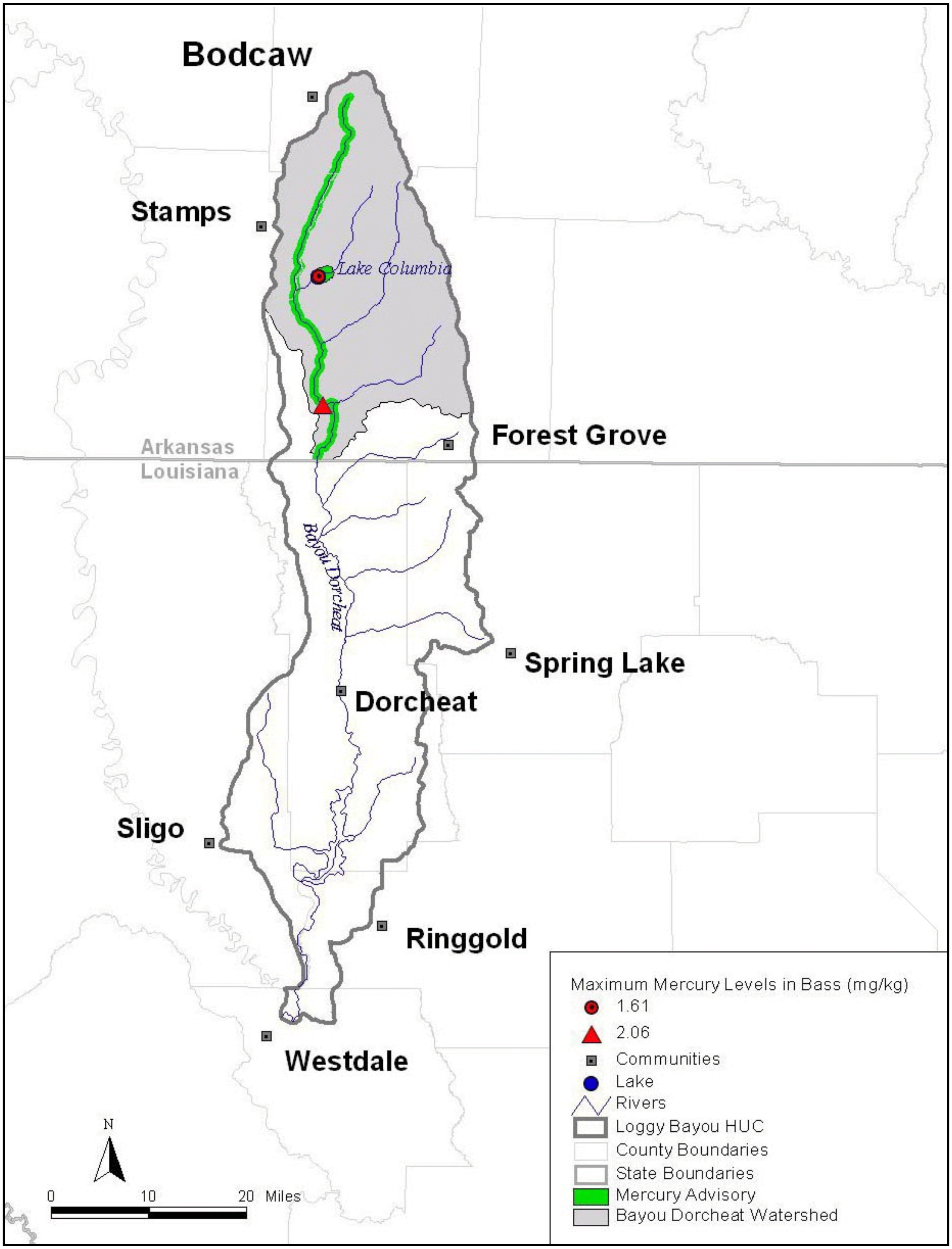


Figure 3.11. Bayou Dorcheat watershed advisory areas and mercury levels in bass.

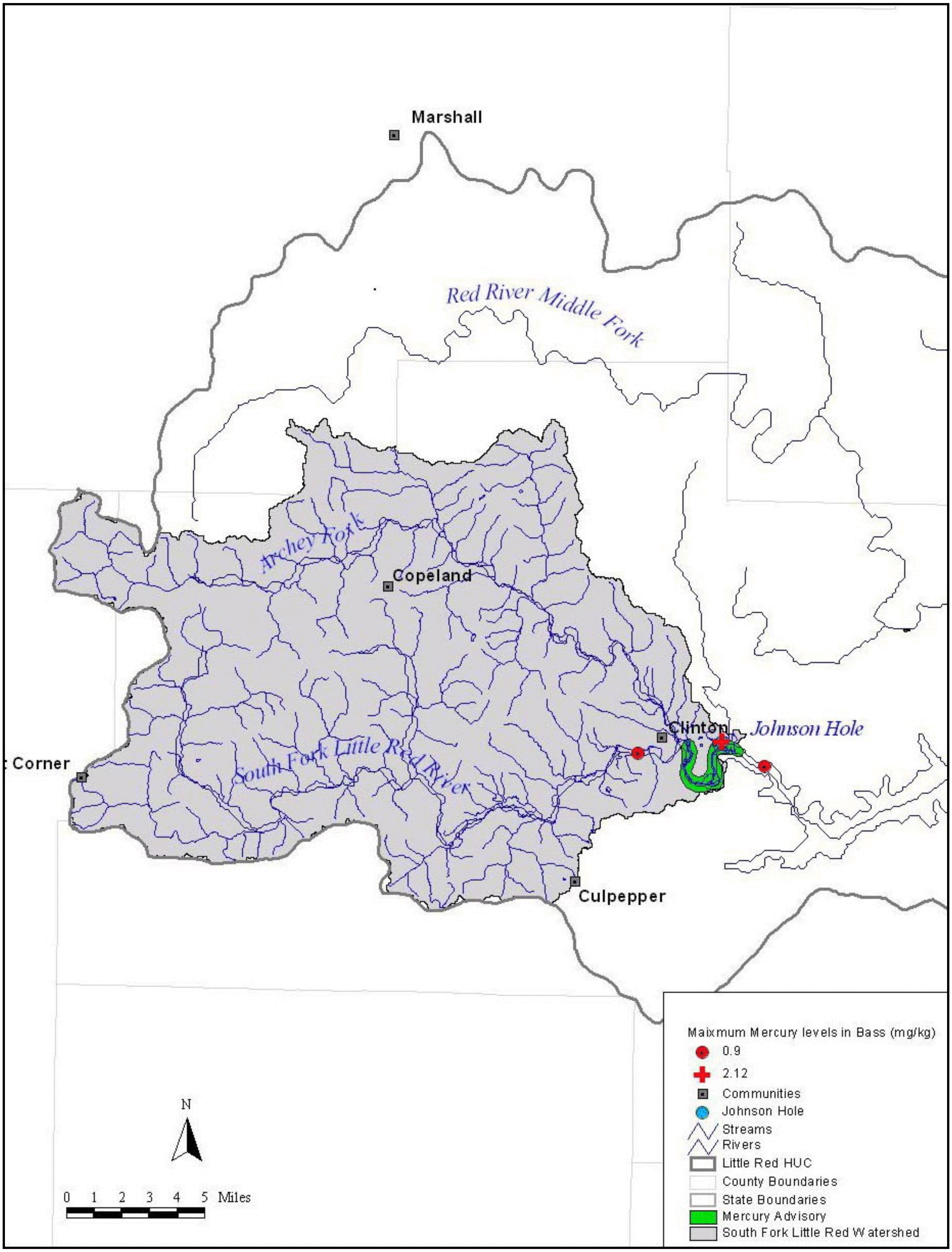


Figure 3.12. South Fork Little Red River watershed advisory areas and mercury levels in bass.

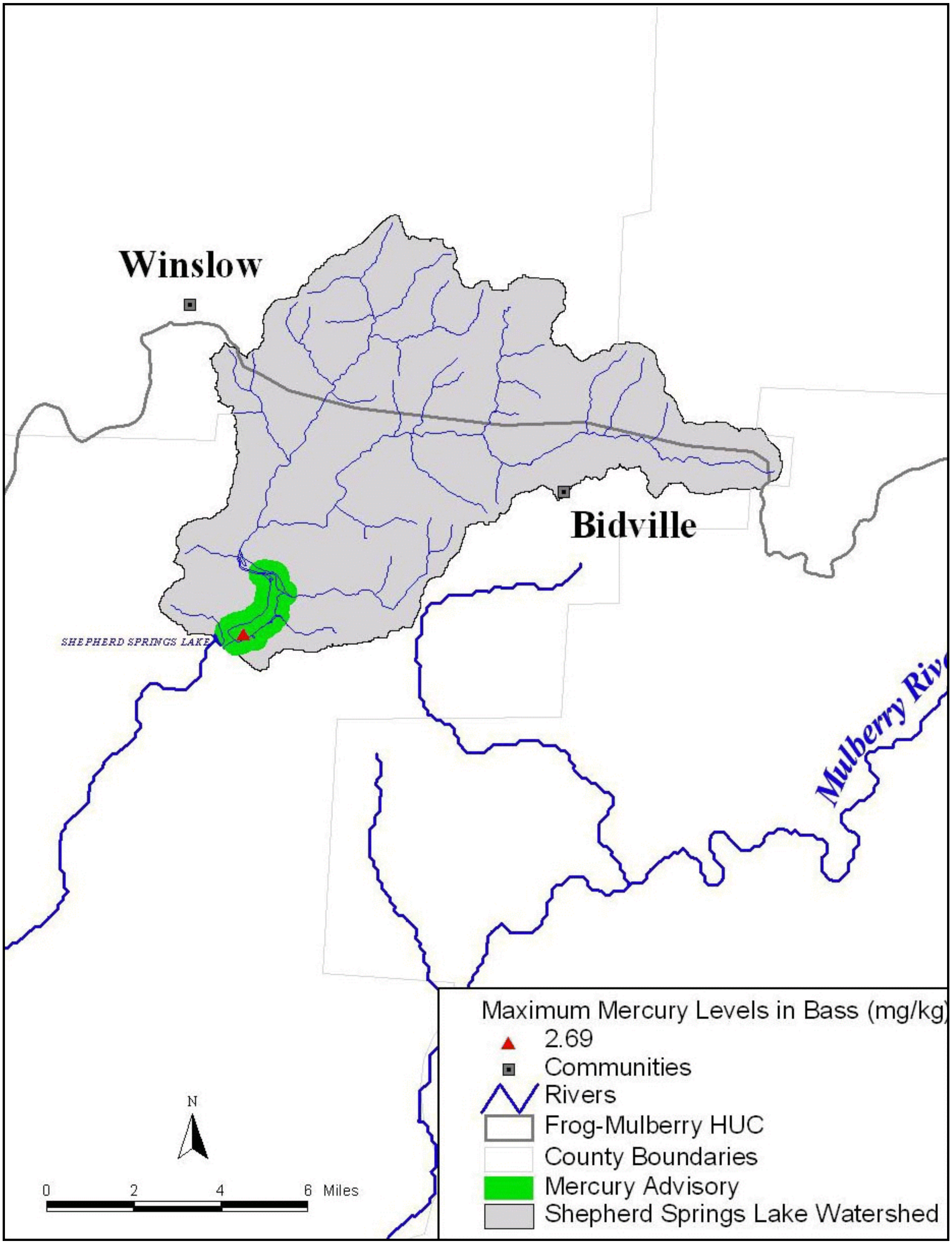


Figure 3.13. Shepherd Springs Lake advisory areas and mercury levels in bass.

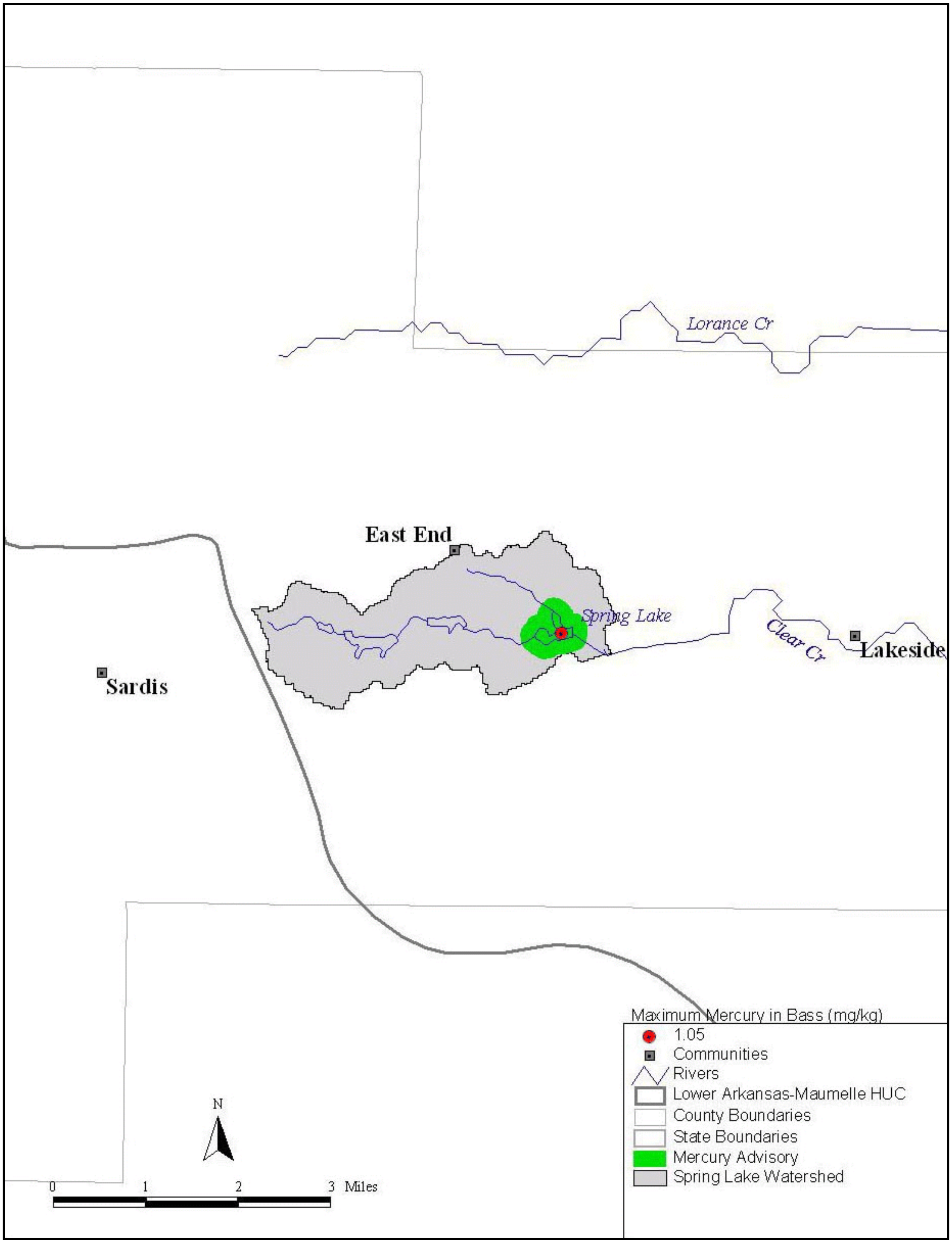


Figure 3.14. Spring Lake watershed advisory areas and mercury levels in bass.

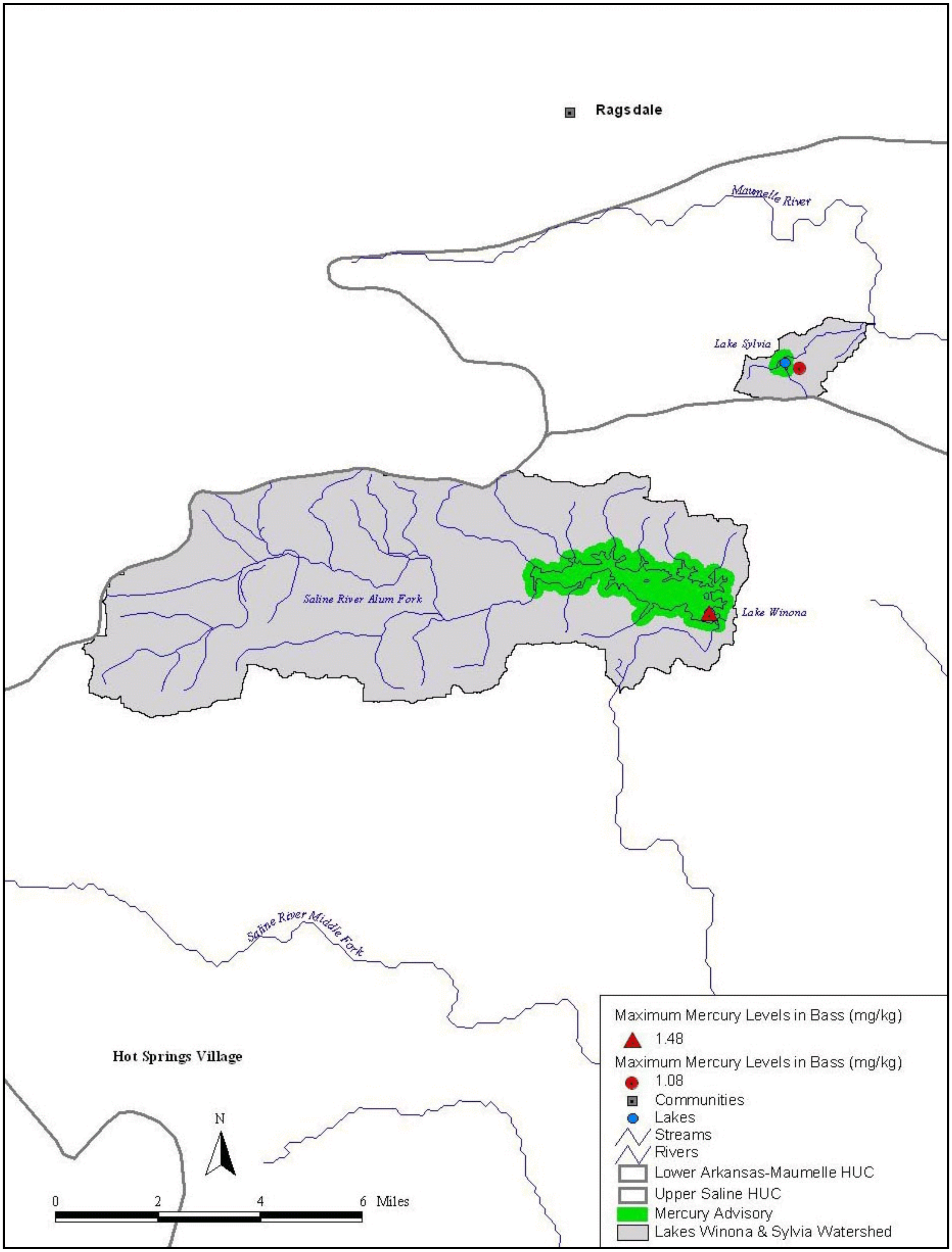


Figure 3.15. Lake Winona and Lake Sylvia watershed advisory areas an mercury levels in bass.

4.0 DEVELOPMENT OF THE TMDL

4.1 Loading Capacity

The loading capacity of waterbodies differ due to (1) inputs or load of mercury to the waterbody, (2) environmental conditions within the waterbody that mediate methylation and bioaccumulation, and (3) the food web or food chain through which mercury bioaccumulates (Armstrong et al.1995). Currently, the water body concentrations of mercury and methylmercury are unknown. In the future, clean sampling and analysis procedures might facilitate the estimation of loading capacity through water column monitoring.

4.2 Conceptual Framework

Mercury is unlike many other metals because it has a volatile phase at ambient temperatures and can be transported in a gaseous, soluble, or particulate form (Figure 4.1). Mercury is emitted to the atmosphere in both elemental gaseous Hg(0) and divalent Hg(II) forms. Anthropogenic direct emissions, natural emissions, and indirect re-emission of previously deposited mercury are major sources of mercury to the atmosphere (Figure 4.1). Gaseous Hg(0) is relatively insoluble and is capable of being transported long distances. However, ozone or other oxidizing agents in the atmosphere can convert Hg(0) to Hg(II). Hg(II) is much more soluble and can sorb onto particulates, resulting in both wet and dry mercury deposition within local (i.e., 100 km from the source, EPA 2001) and regional areas (EPRI 1994). Some Hg(II) can also be chemically reduced to Hg(0). Hg(0) can be transported long distances and contribute to regional and global background concentrations.

Local sources are typically considered to be those sources that are within about a 100 km radius of a site (EPA 2001). Regional sources are loosely defined as other sources within a geographical area such as the Southeast, South, or Upper Midwest, while global sources include intercontinental contributions of mercury. Atmospheric mercury deposition can include contributions from all three sources.

In addition to atmospheric deposition, mercury can also enter waterbodies from point source effluent discharges and watershed nonpoint source contributions. These watershed nonpoint sources include both naturally occurring mercury (e.g., geology) and anthropogenic mercury in soils from current and historical atmospheric deposition (Figure 4.1).

The primary mercury species of concern for bioaccumulation and biomagnification through the food chain, however, are not the inorganic mercury species, but the organic or methylmercury species (Figure 4.2). It is the transformation of inorganic mercury to organic or methylmercury that results in its accumulation and biological magnification through the food chain (Figure 4.2). Methylmercury binds with protein in muscle tissue of fish and other living organisms. Methylmercury is lost very slowly from fish tissue, on the order of years (Trudel and Rasmussen 1997). Therefore, methylmercury concentrations continue to increase throughout the life of the fish as long as methylmercury is in the environment and in its prey species. Older, larger fish typically have higher mercury concentrations than younger, smaller fish.

Recent studies have found that although mercury sulfur complexes have low solubilities in water, complex polysulfidic mercury compounds have greater solubilities than would be indicated from considering only cinnabar, the mercury sulfide ore (Benoit et al. 1999, Paquette and Hely 1995). In addition, it is likely the neutral HgS compound that moves across microbial cell membranes where the mercury is methylated or transformed from inorganic to organic mercury (Benoit et al. 2000). These microorganisms, such as sulfur reducing bacteria, live in anaerobic or zero dissolved oxygen environments in the sediments of wetlands, streams, rivers, and lakes or reservoirs. Therefore, reservoirs with anaerobic hypolimnions can be suitable environments for methylating mercury. New reservoirs (i.e., less than 15 to 20 years old) create environments that are particularly suitable for methylating bacteria so fish tissue mercury concentrations in new reservoirs are typically higher than fish tissue mercury concentrations in older reservoirs. Wetlands also create environments that are very conducive to mercury methylation.

In summary, TMDLs for mercury must consider that mercury can exist as a gas as well as in solution and particulate forms. Mercury loads arise from atmospheric deposition contributed by both local and regional/global emission sources, point source effluent discharges, natural geological formations, and soils. However, after deposition or loading to the system, it can also be lost through volatilization and re-enter the atmospheric pool. It is the organic form as methylmercury that is biologically accumulated and magnified through the food chain. Once in fish, methylmercury is lost very slowly and so accumulates through time.

4.3 TMDL Formulation

A two-step approach was used to estimate loading capacity and the reductions required to achieve the designated fishable use in the watersheds. Loading was estimated from both point and nonpoint sources in the first step, while reductions were estimated based on safe fish tissue Hg concentrations in the second step.

4.3.1 Nonpoint Source Loading Estimates

Nonpoint source load included regional atmospheric deposition inputs, local emission source contributions, and watershed geologic/erosional inputs and watershed soil/erosional inputs.

4.3.1.1 Regional Atmospheric Deposition

Data for regional atmospheric deposition was obtained from the National Atmospheric Deposition Program website. There are no mercury deposition monitoring stations in the state of Arkansas, therefore the two monitoring stations closest to the watershed were utilized (for a map showing locations of all the NADP mercury deposition monitoring sites, see http://nadp.sws.uiuc.edu/mdn/sites.asp). Data from monitoring locations LA10, in Franklin Parish, Louisiana, and TX21, in Gregg County, Texas, were used to represent atmospheric deposition of Hg in the watershed (Figure 4.3). Station LA10 is approximately 126 to 282 miles from the watersheds and Station TX21 is approximately 104 to 272 miles from the watersheds. Station LA10 had wet deposition data available for 1999 and station TX21 had wet deposition data available for 1996 through 1999. Wet deposition is the mercury removed from the atmosphere during rain fall or storm events. Dry deposition is mercury removed from the atmosphere on dust particles, sorption to vegetation, gaseous uptake by plants or other input during non-rainfall periods (EPA 1997). Table 4.1 shows the annual totals for mercury wet deposition measured at the two sites (Note: all tables are located at the end of the section). The total atmospheric deposition was estimated by assuming that dry deposition rates are half of wet deposition rates. Dry deposition rates from 40% to 60% of wet deposition rates are widely accepted (EPA 2001). The estimated total atmospheric deposition was 17.2 $\mu g/m^2/yr$.

Precipitation data was also available from the NADP website (NADP 2000). These data were compared with precipitation data for the watersheds obtained from Hydrosphere (2000) (see Appendix A). The TMDL watersheds received more precipitation than the NADP stations (Table 4.1). Since wet deposition of mercury is related to precipitation, an area receiving more precipitation could be assumed to receive a greater loading of mercury through wet deposition. Therefore, the mercury deposition for the NADP stations was adjusted based on the precipitation data from the NADP sites and the watersheds. Atmospheric deposition correction factors were obtained by dividing the average annual precipitation of the watersheds by the average annual precipitation at stations LA10 and TX21 (1.07 m/yr) (Table 4.1). Multiplying the total atmospheric deposition of 17.2 $\mu g/m^2/yr$ by the correction factors resulted in precipitation corrected total atmospheric deposition rates for each watershed (Table 4.1). Since the dry deposition was assumed to be 50% of the wet deposition, it was included in the adjustment. The corrected total atmospheric deposition rates were within the range (3-30 $\mu g/m^2/yr$) predicted for this area by the RELMAP model (EPA 1997). NADP data and Hydrosphere (2000) data are shown in Table 4.1.

4.3.1.2 Local Atmospheric Deposition

The Louisiana and Texas Deposition Monitoring Stations include both local emission sources similar to those in Arkansas and global/regional input. Local atmospheric deposition for the Arkansas watersheds was estimated based on data from the EPA Office of Air Quality Planning and Standards National Toxics Inventory (NTI) database. The NTI is a complete national inventory of stationary and mobile sources that emit hazardous air pollutants (HAPs). Data from the NTI web site was downloaded using the maximum achievable control technology (MACT) report format. The MACT report includes the number of sources and total 1996 HAP emissions for each MACT source category included in the NTI by county.MACT standards for emission limitations were developed under section 112(d) of the Clean Air Act. The limitations are based on the best demonstrated control technology or practices in similar sources to be applied to major sources emitting one or more of the listed toxic pollutants.

In this TMDL, local sources for a watershed are defined as sources within the watershed and within all counties within a distance of 100 km from the watershed boundary. The area within which these local sources are located is referred to as the "airshed". The NTI MACT report format has sources listed by county, therefore, the airshed boundary is determined by county boundaries and if a portion of a county falls within 100 km of the watershed boundary, then the entire county is included as part of the airshed. The county-based airshed boundary for each watershed is shown in Figures 4.4 through 4.9. The mercury emissions for each MACT category found within the airsheds are included in Appendix C. Table 4.2 shows the areas of each airshed and the local Hg(II) emissions calculated from the MACT data that contribute to the local atmospheric deposition. MACT source categories not included in Appendix C (e.g. medical waste incineration) were not present in the airsheds, and were not included as local sources in the TMDLs. MACT source categories not included in Appendix C could contribute to the global/regional atmospheric mercury load to the watersheds.

The distance from the emission source, the forms of the mercury in the emissions, other pollutants in the emissions and the atmosphere, and the weather patterns of precipitation are important factors in determining where mercury released to the air will deposit. Divalent mercury [Hg(II)] is the dominant form of mercury in both rainfall and most dry deposition processes. An estimate of the Hg(II) emitted from MACT category sources in the airshed was calculated based on source speciation percentages (EPA 2000b, Russ Bullock personal communication 2001). The speciation percentages used to estimate the Hg (II) emissions are shown in Appendix C. The mercury deposition rate for each watershed due to local sources was determined by dividing the total Hg(II) emissions for each airshed by the airshed area (Table 4.2). This calculation is a simplification of the methodology used in the Savannah River mercury TMDL (EPA 2001). The global/regional deposition rate was set equal to the precipitation corrected total atmospheric deposition rate minus the local source deposition rate (Table 4.2). Based on the analysis of local sources, the majority of the atmospheric mercury deposition to the watersheds can be attributed to global/regional sources.

The local source and global/regional deposition rates were used to determine the mercury loading to lakes, reservoirs, and wetlands in each of the watersheds. Table 4.3 shows the total area of the watersheds and the area of the watersheds covered by streams, lakes, reservoirs, and wetlands. The sum of the stream, lake, reservoir, and wetland areas was multiplied by the local and global/regional mercury atmospheric deposition rates to obtain the direct mercury atmospheric loads to the waterbodies on each watershed. The portions of the total mercury deposition that can be attributed to local sources versus global/regional sources in each watershed are shown in Table 4.3.

Indirect atmospheric mercury contributions in overland flow during rain events was not estimated. The watersheds are primarily forested (Table 4.4), and overland flow during rain events in forested lands is minimal (Waring and Schlesinger 1985). Therefore, it was assumed that indirect atmospheric contributions via overland flow during rain events would not be significant.

4.3.1.3 Watersheds Sediment Mercury Loading

Mercury can also enter the waterbodies sorbed to sediments. Sediment loads for the watersheds were based on erosion rates for agricultural, barren, and forestland areas reported in literature. The land use areas were based on USGS land use data from the 1970's provided as part of BASINS version 2.0 (1999). Erosion rates were set based on information from Bloodworth and Berc (1998), Handbook of Nonpoint Pollution (Novotny and Chesters 1981), and Ozark-Ouachita Highlands Assessment Report (USDA FS 1999). Cropland erosion rates reported in these sources average 3.4 tons/acre/year. Cropland with highly erodible soils reportedly have erosion rates of 6.2 to 6.4 tons/acre/year and cropland with soils that are not highly erodible reportedly have erosion rates of 2.3 to 2.4 tons/acre/year. Reported forestland erosion rates ranged from 0.2 to 0.8 tons/acre/year. There was a small percentage of barren land within some of the watersheds. Sediment loads for barren lands were calculated using cropland erosion rates. Table 4.4 shows the total area, agricultural area, forestland area, and barren land area for the watersheds. Percentages of the watersheds in these land uses are also included. Table 4.5 shows the sediment loads calculated using these land use areas and the erosion rates discussed above.

Mercury in sediment was assumed to come from two sources—geologic weathering and atmospheric deposition. Given that geologic weathering contributes to soils, a portion of the mercury in the soils would come from the underlying geology, which is known to contain mercury (Armstrong et al. 1995). In this TMDL study, the portion of the sediment mercury load contributed by geologic weathering was estimated (sediment/geologic mercury) and labeled as the background load. In addition, on-going and historical atmospheric mercury deposition over the past several decades, if not centuries, has also contributed mercury to the soils. While some of this mercury was likely re-emitted to the atmosphere, some of this previously deposited mercury would remain sorbed to the soils and could be transported to waterbodies. This portion of the sediment mercury load was reported as sediment/deposited mercury.

A number of measurements of mercury in rock formations in the Ouachita Mountains (Stone et al. 1995) and soils in the Ouachita River basin (Armstrong et al. 1995) were available. Figure 4.10 shows the sampling locations. Mercury concentrations measured in both rock and soils in Arkansas exhibited a large degree of variability (Figure 4.11). To get an idea of the range of possible geologic mercury and deposited mercury in sediment loads, three loads were calculated. The upper boundary loads were calculated using 90th percentile rock (0.25 mg/kg) and soil (0.3 mg/kg) mercury concentrations measured in Arkansas. The lower boundary loads were calculated using 10th percentile rock (0.01 mg/kg) and soil (0.02 mg/kg) mercury concentrations from the same data set. The load considered to be most realistic was calculated using the geometric mean of shale (0.09 mg/kg) and soil (0.16 mg/kg) mercury concentrations. Shale mercury was used for the most likely load calculation because it is common in the Ouachita and Boston Mountains and is the most easily erodible rock analyzed (Armstrong et al. 1995). Therefore it was deemed the most likely to contribute to the sediment mercury load.

Estimates of the sediment/geologic mercury loads for the watersheds were calculated by multiplying the rock mercury concentrations discussed above by the total watershed sediment loads in Table 4.5. The sediment/deposited mercury loads were estimated by multiplying the non-geologic soil mercury concentrations by the sediment loads. The non-geologic soil mercury concentrations were calculated as the soil mercury concentrations minus the rock mercury concentrations. Therefore, the upper boundary non-geologic soil mercury concentration was 0.05 mg/kg, the lower boundary concentration was 0.01 mg/kg, and the most likely concentration was 0.07 mg/kg. The loads calculated using these soil and rock concentrations are shown in Table 4.6.

4.3.2 Point Source Loading Estimate

There were no NPDES permitted sources with mercury limits in their permit discharging in any of the watersheds. Municipal wastewater treatment facilities were assumed to discharge some mercury because mercury at low levels has been measured in wastewater treatment plants (WWTPs) in Arkansas and other US regions. ADEQ conducted a monitoring study of five WWTPs in Arkansas using clean sampling procedures and ultra-trace level analyses and found an average concentration of about 15 ng/L in municipal discharges (Allen Price, ADEQ, personal communication 2001).

Because mercury had been found in WWTP discharges in Arkansas, an estimate of the contribution of mercury to the watersheds from municipal WWTPs was calculated (Table 4.7). A list of the municipal WWTPs in each watershed was obtained from the PCS search done for NPDES permitted facilities (Appendix B). A mercury concentration of 15 ng/L was assumed for each WWTP. This concentration was multiplied by the design flow for the municipal WWTPs to estimate the point source mercury loads. Design flows were included in the results of the PCS search.

4.3.3 Load Reduction Estimation

Load reduction estimates were based on concentrations of mercury in largemouth bass in the waterbodies of concern. Mercury concentrations have been measured in largemouth bass collected throughout Arkansas (Armstrong et al. 1995). These data are the basis for the fish consumption advisiories that have been issued for the waterbodies included in this TMDL. Although the fish consumption advisories were issued based on maximum measured tissue mercury concentrations, the average of measured tissue mercury concentrations in largemouth bass collected in the waterbodies of concern were used to calculate the decrease in fish tissue concentrations needed to result in a target fish tissue mercury concentration. Average fish tissue mercury concentrations have been used to calculate load reductions in other mercury TMDLs, and EPA considers such load reductions to be protective of human health.

If the mercury body burden of the primary fish species of concern (largemouth bass) were reduced to <1.0 mg/kg the waterbodies would achieve their designated, fishable uses with regard to mercury. The mercury reductions required to achieve the designated uses in the waterbodies of concern were based on a target level of 0.8 mg/kg fish tissue mercury concentration. This fish tissue concentration provides a 20% margin of safety in the target level. A linear relationship was assumed between mercury source reductions and fish tissue mercury concentrations. This relationship is consistent with steady-state assumptions and the use of bioaccumulation factors. However, interactions of both inorganic and organic mercury with sulfide, organic carbon, and other water quality constituents can affect its bioavailability for both methylation and uptake (Armstrong et al.1995, EPA 1997, 1998).

In order to establish the reduction needed in average largemouth bass tissue mercury concentrations to achieve designated uses in the waterbodies of concern, the average measured largemouth bass tissue mercury concentrations were divided by the target tissue mercury concentration (0.8 mg/kg). A hazard quotient is directly applied to estimate the load reduction (RF), as illustrated in the following equations:

$RF = MC/SC$, where

$RF =$ Reduction Factor

MC = Measured tissue mercury concentration (worst case species of bass and water body average concentration, mg/kg wet weight)
SC = Safe tissue mercury concentration (with margin of safety, mg/kg wet weight)

and,

TMDL = (EL/RF) x SF, where

TMDL = total maximum daily load (average value in $ng/m^2/d$)
RF = Reduction Factor
EL = Existing total load (includes point and nonpoint sources)
SF = Site specific factor(s) (requires study, but could be based on measured sulfate, organic carbon, alkalinity or pH values that influence mercury methylation and bioaccumulation. Assumed to be 1 in this study).

This approach follows and builds on the precedence established in *Mercury TMDLs for Segments Within Mermentau and Vermillion-Teche River Basins* (EPA 2000). Those averages of measured tissue mercury concentrations in largemouth bass collected in the waterbodies of concern that are greater than 0.8 mg/kg are listed in Table 4.8, along with the calculated reduction factors for each waterbody. Average measured largemouth bass tissue mercury concentrations were less than 0.8 mg/kg for Lake Nimrod and Lake Winona, so they were excluded from the calculations. Averages of the tissue concentrations and reduction factors were also calculated for each watershed from the values for the waterbodies of concern within the watershed, and included in Table 4.8.

To estimate the total and methylmercury concentrations that might be occurring in the water column given the reported fish tissue mercury concentrations, the average bioaccumulation factor (BAF) used in the EPA Mercury Report to Congress (EPA 1997) was used to back calculate to water methylmercury concentrations (Table 4.9). The ratio of MeHg/THg ranges from 0.01 to 0.3 (EPA 1998, Krabbenhoft et al. 1999). A MeHg/THg ratio of 0.1 was used to estimate water total mercury concentrations (Table 4.9). Both the methylmercury and total mercury concentrations appeared to be reasonable estimates of concentrations that might be expected in the watersheds.

4.4 Current Load

The estimated total mercury loads to the watersheds on both an annual and a daily basis are shown in Tables 4.10 through 4.15 . The municipal WWTP point source contributions are minor (<1%) compared to the atmospheric and watershed nonpoint source contributions. The upper boundary and most likely geologic erosion and soil erosion loads account for the majority of the mercury loads to the watersheds. The lower boundary geologic erosion and soil erosion loads also account for the majority of the mercury load for Fourche La Fave, South Fork Little Red River, and Shepherd Springs Lake watersheds. In the Bayou Dorcheat and Lakes Winona and Sylvia watersheds, regional atmospheric deposition accounts for the majority of the mercury load with the lower boundary geologic erosion and soil erosion loads. Therefore, geology, soils, and regional atmospheric deposition are the primary sources of mercury loading to the watersheds.

4.5 TMDLs

Target mercury loads for each watershed were calculated using the watershed average reduction factors (see Section 4.3.3, and Table 4.8). The target loads are shown in Tables 4.10 through 4.15. The load allocations for the TMDLs for each watershed are shown in Tables 4.16 through 4.21. Annual mercury loads are used in the load allocations because the concern with this TMDL study is the long term accumulation of mercury, rather than short term acute toxicity events.

4.5.1 Wasteload Allocation

In watersheds with NPDES point sources, the point sources (i.e., municipal WWTPs) contribute less than 1% of the current mercury load to the watershed. Even if the TMDLs for these watersheds were to allocate none of the calculated allowable load to NPDES point sources (i.e., a wasteload allocation of zero), the required reduction in the watershed mercury load would not be attained because of the very high mercury loadings from nonpoint and background sources. At the same time, however, EPA recognizes that mercury is an enviromentally persistent, bioaccumulative toxic with detrimental effects to human fetuses even at minute quantities, and as such, should be eliminated from discharges to the extent practicable. Taking these two considerations into account, this TMDL provides that mercury contributions from the municipal WWTPs not exceed the mercury water quality standard for Arkansas (12 ng/L).

4.5.2 Load Allocation

The majority of the mercury load to the watersheds comes from nonpoint sources. Therefore, nonpoint mercury loads must be reduced to achieve the target watershed mercury loads. The reductions in nonpoint mercury loads to the watersheds shown in the TMDL allocations (Tables 4.16 through 4.21) are discussed below.

Reductions in atmospheric mercury loads are expected as a result of implementation of regulations to reduce/limit mercury emissions from certain MACT source categories. In the United States, a 50% reduction in mercury emissions is expected as a result of implementing existing regulations to limit mercury emissions. Therefore, a 50% reduction in the regional atmospheric mercury loads to all of the watersheds is assumed for the TMDL allocations. The regional atmospheric mercury loads in the TMDLs are half the current loads.

Reductions in the local atmospheric mercury loads to the watersheds would also be expected. Table 4.22 summarizes the expected percent reductions in the local atmospheric mercury loads from local sources to the airsheds as a result of implementing existing MACT mercury emissions limits. The local atmospheric mercury loads in the TMDLs are the current loads reduced by the percentages listed in Table 4.22.

Reducing the atmospheric deposition should reduce the amount of deposited mercury in sediments. Therefore, a reduction in the sediment/deposited mercury load would be expected as a result of implementation of MACT mercury emissions regulations since mercury deposited in soils come from both local and regional sources. Table 4.23 shows the percent reduction in the current total atmospheric loads (regional plus local) to the watersheds resulting from implementation of MACT mercury emissions regulations. The sediment/deposited mercury loads in the TMDLs are the current sediment/deposited mercury loads reduced by the percentages listed in Table 4.23.

Reductions in atmospheric deposition of mercury due to implementing MACT emission regulations were all that was needed to achieve the target watershed mercury loads for Shepherd Springs Lake, Spring Lake (except upper boundary scenario), and Lakes Winona and Sylvia watersheds. The remaining watersheds required further reductions of their mercury loads.

Additional reductions in the sediment mercury load to the waterbodies could be achieved by implementing best management practices (BMPs) to reduce the amount of eroded material entering the waterbodies. Although the watersheds are mostly forested, agricultural land uses (with higher erosion rates) often occur along streams in the river valleys (see land use maps in Chapter 2). Applying BMPs in the watersheds with agricultural and barren land uses would reduce the sediment mercury loads to the waterbodies from both the deposited mercury and the geologic mercury categories. Table 4.24 summarizes the reductions in the current sediment load required for watersheds with agricultural and/or barren land uses to achieve their target mercury loads. These reductions were determined by an iterative process of trying out percent reductions until a value as close as possible to the target watershed mercury load was achieved. These reduced sediment loads were used to calculate the sediment mercury loads shown in the TMDL allocations. Sediment/geologic mercury, and sediment/deposited mercury loads for the TMDLs were calculated by multiplying the reduced sediment loads by the appropriate geologic or non-geologic mercury concentrations (see Section 4.3.1.3 for more information on sediment load calculations). The sediment/deposited mercury loads calculated using the reduced sediment loads were then reduced by the percentages listed in Table 4.23 to account for changes in both erosion rates and atmospheric deposition of mercury to soils.

4.5.3 Reserve Load

The conservative estimates used throughout these analyses, including the conservative reduction factors, should provide an unallocated reserve for mercury loading to the watersheds. However, watershed nonpoint sources of geologic and previously deposited mercury might sustain fish consumption advisories even if all other mercury sources were eliminated.

Table 4.1. Deposition rate estimates for the watersheds based on NADP data.

NADP Data Summary				Precipitation Data (1997 - 1999)			
Station	Year	Rain Gauge (m/yr)	Wet Hg Deposition (μg/m²/yr)	HUC	Average Precipitation (m/yr)	Atmospheric Deposition Correction Factor	Precipitation Corrected Total Atmospheric Deposition Rate (μg/m²/yr)
TX21	1996	0.8	9.0	11110206	1.33	1.24	21.3
TX21	1997	1.3	13.0	11140203	1.54	1.44	24.6
TX21	1998	1.1	11.6	11010014	1.23	1.15	19.7
TX21	1999	0.9	10.3	11110201	1.35	1.26	21.6
LA10	1999	1.3	13.3	11110207	1.19	1.11	19.1
	Average	1.07	11.4	08040203 and 11110207	1.27	1.18	20.3

Dry + Wet = Average Wet Deposition x 1.5 = 17.2 μg/m²/yr
Precipitation Corrected Total Atmospheric Deposition Rate = Atmospheric Deposition Correction Factor x 17.2 μg/m²/yr
Atmospheric Deposition Correction Factor = HUC Average Precipitation / NADP Rain Gauge Average

Table 4.2. Local point source emissions within the airsheds based on NTI MACT report data.

Watershed	Airshed Area (km²)	MACT Local Source Hg(II) Emissions in Airshed (g/yr)	Local Source Deposition Rate (μg/m²/yr)	Global/Regional Deposition Rate (μg/m²/yr)
Fourche La Fave	108,875	293,103	2.69	18.6
Bayou Dorcheat	84,798	255,316	3.01	21.6
South Fork Little Red	62,821	76,131	1.21	18.5
Shepherd Springs Lake	57,522	146,378	2.54	19.0
Spring Lake	53,793	99,163	1.84	17.2
Lake Winona/Lake Sylvia	60,423	94,426	1.56	18.8

Notes:

MACT local source Hg(II) emissions from data in Appendix B
Local Source Deposition Rate = MACT Local Source Hg(II) Emissions/Airshed Area
Global/Regional Deposition Rate = Precipitation Corrected Total Atmospheric Deposition Rate minus Local Source Deposition Rate
Precipitation Corrected Total Atmospheric Deposition Rate from Table 4.1

Table 4.3. Atmospheric mercury deposition load to the entire watersheds.

Watershed	Streams (acres)	Lakes and Reservoirs (Acres)	Wetlands (acres)	Streams, Lakes, Reservoirs, and Wetlands (km^2)	Local Hg Deposition (g/yr)	Global/Regional Hg Deposition (g/yr)
Fourche La Fave	0*	5,802	784	26.65	72	496
Bayou Dorcheat	0	120	32,986	134.0	403	2,896
South Fork Little Red	0	279	0*	1.13	1.4	21
Shepherd Springs Lake	0	270	0	1.09	2.8	21
Spring Lake	0	158	0	0.64	1.2	11
Lake Winona & Lake Sylvia	0	1,272	0	5.15	8.0	96

* No estimate of areas in streams and canals, or wetlands available in the BASINS land use data for these watersheds.

Notes:
Areas based on land use data from BASINS 2.0.
Local Hg Deposition = stream, lakes, reservoirs and wetland areas * local source deposition rate from Table 4.2.
Global/Regional Hg Deposition = stream, lakes, reservoirs and wetland areas * global/regional deposition rate from Table 4.2.

Table 4.4. Sources of erosion within the watersheds.

Watershed	Watershed Area (acre)	Agricultural Land		Forest Land		Barren Land		Total Percent of Watershed
		Acres	Percent of Watershed Area	Acres	Percent of Watershed Area	Acres	Percent of Watershed Area	
Fourche La Fave	715,688	106,197	14.8	601,263	84.0	33	0.004	98.9
Bayou Dorcheat	324,106	62,946	19.4	222,048	68.5	150	0.05	88.0
South Fork Little Red	177,212	21,572	12.2	153,910	86.9	—	—	99.0
Shepherd Springs Lake	44,908	3,936	8.8	40,533	90.3	---	---	99.0
Spring Lake	2,735	16	0.6	2,429	88.8	63	2.3	91.7
Lake Winona/Lake Sylvia	34,320	—	—	33,048	96.3	—	---	96.3

Note:
Land use areas based on land use data from BASINS 2.0
Watershed areas calculated by summing reported land use areas.

Table 4.5. Sediment load estimated from erosion sources in the watersheds.

Watershed	Agricultural Land Erosion Rate (tons/acre/yr)	Agricultural Land Sediment (tons/yr)	Forest Land Erosion Rate (tons/acre/yr)	Forest Land Sediment (tons/yr)	Barren Land Erosion Rate (tons/acre/yr)	Barren Land Sediment (tons/yr)	Total Sediment (tons/yr)
Fourche La Fave	2.4	254,873	0.2	120,253	2.4	79	375,205
Bayou Dorcheat	2.4	151,070	0.2	44,410	2.4	361	195,841
South Fork Little Red	2.4	51,773	0.2	30,782	2.4	—	82,555
Shepherd Springs Lake	2.4	9,446	0.2	8,107	2.4	—	17,553
Spring Lake	2.4	38	0.2	486	2.4	151	675
Lake Winona/Lake Sylvia	2.4	—	0.2	6,610	2.4	—	6,610

Note:
Land use data from BASINS 2.0.
Average land use based erosion rates from literature.

Table 4.6. Mercury loading to watersheds due to erosion.

Watershed	Scenario	Sediment/Geologic Mercury (g/yr)	Sediment/Deposited Mercury (g/yr)
Fourche La Fave	Upper Boundary	85,095	17,019
	Most Likely	30,634	23,827
	Lower Boundary	3,404	3,404
Bayou Dorcheat	Upper Boundary	44,416	8,883
	Most Likely	15,990	12,436
	Lower Boundary	1,777	1,777
S. Fork Little Red River	Upper Boundary	18,723	3,745
	Most Likely	6,740	5,242
	Lower Boundary	749	749
Shepherd Springs Lake	Upper Boundary	3,981	796
	Most Likely	1,433	1,115
	Lower Boundary	159	159
Spring Lake	Upper Boundary	153	31
	Most Likely	55	43
	Lower Boundary	6	6
Lake Winona and Lake Sylvia	Upper Boundary	1,499	300
	Most Likely	540	420
	Lower Boundary	60	60

Note: Sediment/Geologic mercury: Upper Boundary rock mercury = 0.25 mg/kg, Most Likely rock mercury = 0.09 mg/kg, Lower Boundary rock mercury = 0.01 mg/kg

Sediment/Deposited mercury: Upper Boundary non-geologic mercury = 0.05 mg/kg, Most Likely non-geologic mercury = 0.07 mg/kg, Lower Boundary non-geologic mercury = 0.01 mg/kg

Mercury loads = sediment load * geologic or non-geologic mercury concentrations.

Geologic mercury concentrations from measured mercury concentrations in rock

Non-geologic mercury concentrations = measured soil mercury concentrations - rock mercury concentrations

Measured rock and soil mercury concentrations from Armstrong et al. 1995.

Table 4.7. Mercury load estimated from municipal wastewater treatment plants assuming an average concentration of 15 ng/L.

Watershed	Discharge from Municipal Sources (MGD)	Estimated Mercury* (ng/L)	Mercury Load (ng/day)	Mercury Load (g/yr)
Fourche La Fave	0.2	15	1.19e+07	4.4
Bayou Dorcheat	3.05	15	1.73e+08	63.3
South Fork Little Red	2.7	15	1.53e+08	56
Shepherd Springs Lake	---	---	---	---
Spring Lake	---	---	---	---
Lake Winona/Lake Sylvia	---	---	---	---

* Average mercury concentration measured in Arkansas WWTPs (Allen Price, ADEQ, personal communication 2001).

Table 4.8. Reduction Factor (RF) needed to reduce average fish tissue mercury concentrations to target level (0.8 mg/kg) and achieve fishable designated use.

Watershed	Waterbody	Average Largemouth Bass Hg Concentration (mg/kg)	RF to Achieve Target Level
Fourche La Fave	Cove Creek Lake	1.36	1.70
	Dry Fork Lake	1.29	1.61
	Fourche La Fave River	0.89	1.11
	Average for Fourche La Fave watershed	1.18	1.47
Bayou Dorcheat	Lake Columbia	0.85	1.06
	Bayou Dorcheat	2.06	2.58
	Average for Bayou Dorcheat watershed	1.46	1.82
Lake Sylvia and Lake Winona	Lake Sylvia	0.87	1.1
Shepherd Springs Lake	Shepherd Springs Lake	0.82	1.02
South Fork Little Red	South Fork Little Red River - Johnson Hole	1.00	1.25
Spring Lake	Spring Lake	1.05	1.31

Note: Largemouth bass concentrations from Armstrong et al. 1995

Table 4.9. Water methylmercury concentrations back-calculated from fish tissue mercury concentrations. Total mercury concentrations estimated from MeHg:THg ratio.

Location	**Maximum LMB Hg Concentration (mg/kg)**	**MeHg Conc. in Water Back-Calculated from BAF** (ng/L)**	**Total Hg Conc. in Water from MeHg:THg Ratio+ (ng/L)**
Cove Creek Lake	2.43	0.4	4.0
Bayou Dorcheat	2.06	0.3	3.0
Dry Fork Lake	2.58	0.4	4.0
Fourche La Fave River	1.24	0.2	2.0
Lake Columbia	1.61	0.2	2.0
Lake Nimrod	1.26	0.2	2.0
Lake Sylvia	1.08	0.2	2.0
Lake Winona	1.48	0.2	2.0
Shepherd Springs Lake	2.69	0.4	4.0
South Fork Little Red River	0.9	0.1	1.0
South Fork Little Red River - Johnson Hole	2.12	0.3	3.0
South Fork Little Red River - Old Water Works	0.52	0.08	0.8
Spring Lake	1.05	0.2	2.0

**BAF = 6.8 X 10^6 geometric mean (EPA 1997)
+ MeHg: THg Ratios ~ 0.01 to 0.3, 0.1 used for conversion to THg (EPA 1998)

Table 4.10. Estimated current mercury load to Fourche La Fave watershed.

Source Type	Upper Boundary			Most Likely			Lower Boundary		
	Load		Percent of Total Load	Loading Rate		Percent of Total Load	Loading Rate		Percent of Total Load
	(g/yr)	(g/d)		(g/yr)	(g/d)		(g/yr)	(g/d)	
Point Source									
Municipal WWTPs[1]	4.4	0.01	0.0%	4.4	0.01	0.0%	4.4	0.01	0.1%
Non-Point Source									
Regional Atmospheric Deposition[2]	496	1.4	0.5%	496	1.4	0.9%	496	1.4	6.7%
Local Atmospheric Deposition[2]	72	0.2	0.1%	72	0.2	0.1%	72	0.2	1.0%
Sediment/ Deposited Mercury[3]	17,019	47	16.6%	23,827	65	43.3%	3,404	9.3	46.1%
Background									
Sediment/ Geologic Mercury[3]	85,095	233	82.9%	30,634	84	55.7%	3,404	9.3	46.1%
Watershed Total	102,686	281	100%	55,033	151	100%	7,380	20	100%
Watershed Reduction Factor[4]	1.47	—		1.47	—		1.47	—	
Target Watershed Load[5]	69,854	—		37,437	—		5,020	—	

[1] From Table 4.7
[2] From Table 4.3
[3] From Table 4.6
[4] From Table 4.8
[5] Target watershed load = watershed total/watershed reduction factor

Table 4.11. Estimated current mercury load to Bayou Dorcheat watershed.

Source Type	Upper Boundary			Most Likely			Lower Boundary		
	Load		Percent of Total Load	Loading Rate		Percent of Total Load	Loading Rate		Percent of Total Load
	(g/yr)	(g/d)		(g/yr)	(g/d)		(g/yr)	(g/d)	
Point Source									
Municipal WWTPs[1]	63	0.2	0.1%	63	0.2	0.2%	63	0.2	0.9%
Non-Point Source									
Regional Atmospheric Deposition[2]	2,896	7.9	5.1%	2,896	7.9	9.1%	2,896	7.9	41.9%
Local Atmospheric Deposition[2]	403	1.1	0.7%	403	1.1	1.3%	403	1.1	5.8%
Sediment/ Deposited Mercury[3]	8,883	24	15.7%	12,436	34	39.1%	1,777	4.9	25.7%
Background									
Sediment/ Geologic Mercury[3]	44,416	122	78.4%	15,990	44	50.3%	1,777	4.9	25.7%
Watershed Total	56,661	155	100%	31,788	87	100%	6,916	19	100%
Watershed Reduction Factor[4]	1.82	—		1.82	—		1.82	—	
Target Watershed Load[5]	31,132	—		17,466	—		3,800	—	

[1] From Table 4.7
[2] From Table 4.3
[3] From Table 4.6
[4] From Table 4.8
[5] Target watershed load = watershed total/watershed reduction factor

Table 4.12. Estimated current mercury load to South Fork Little Red watershed.

Source Type	Upper Boundary			Most Likely			Lower Boundary		
	Load		Percent of Total Load	Loading Rate		Percent of Total Load	Loading Rate		Percent of Total Load
	(g/yr)	(g/d)		(g/yr)	(g/d)		(g/yr)	(g/d)	
Point Source									
Municipal WWTPs[1]	56	0.2	0.2%	56	0.2	0.5%	56	0.2	3.6%
Non-Point Source									
Regional Atmospheric Deposition[2]	21	0.1	0.1%	21	0.1	0.2%	21	0.1	1.3%
Local Atmospheric Deposition[2]	1.4	0.004	0.0%	1.4	0.004	0.0%	1.4	0.004	0.1%
Sediment/ Deposited Mercury[3]	3,745	10	16.6%	5,242	14	43.5%	749	2.1	47.5%
Background									
Sediment/ Geologic Mercury[3]	18,723	51	83.0%	6,740	18	55.9%	749	2.1	47.5%
Watershed Total	22,546	62	100%	12,060	33	100%	1,576	4.3	100%
Watershed Reduction Factor[4]	1.25	—		1.25	—		1.25	—	
Target Watershed Load[5]	18,037	—		9,648	—		1,261	—	

1 From Table 4.7
2 From Table 4.3
3 From Table 4.6
4 From Table 4.8
5 Target watershed load = watershed total/watershed reduction factor

Table 4.13. Estimated current mercury load to Shepherd Springs Lake watershed.

Source Type	Upper Boundary Load (g/yr)	Upper Boundary Load (g/d)	Upper Boundary Percent of Total Load	Most Likely Loading Rate (g/yr)	Most Likely Loading Rate (g/d)	Most Likely Percent of Total Load	Lower Boundary Loading Rate (g/yr)	Lower Boundary Loading Rate (g/d)	Lower Boundary Percent of Total Load
Point Source									
Municipal WWTPs[1]	0	0	0.0%	0	0	0.0%	0	0	0.0%
Non-Point Source									
Regional Atmospheric Deposition[2]	21	0.06	0.4%	21	0.06	0.8%	21	0.06	6.1%
Local Atmospheric Deposition[2]	2.8	0.01	0.1%	2.8	0.01	0.1%	2.8	0.01	0.8%
Sediment/ Deposited Mercury[3]	796	2.2	16.6%	1,115	3.1	43.3%	159	0.4	46.6%
Background									
Sediment/ Geologic Mercury[3]	3,981	11	82.9%	1,433	3.9	55.7%	159	0.4	46.6%
Watershed Total	4,801	13	100%	2,572	7.0	100%	342	0.9	100%
Watershed Reduction Factor[4]	1.02	—		1.02	—		1.02	—	
Target Watershed Load[5]	4,707	—		2,521	—		335	—	

[1] From Table 4.7
[2] From Table 4.3
[3] From Table 4.6
[4] From Table 4.8
[5] Target watershed load = watershed total/watershed reduction factor

Table 4.14. Estimated current mercury load to Spring Lake watershed.

Source Type	Upper Boundary			Most Likely			Lower Boundary		
	Load		Percent of Total Load	Loading Rate		Percent of Total Load	Loading Rate		Percent of Total Load
	(g/yr)	(g/d)		(g/yr)	(g/d)		(g/yr)	(g/d)	
Point Source									
Municipal WWTPs[1]	0	0	0.0%	0	0	0.0%	0	0	0.0%
Non-Point Source									
Regional Atmospheric Deposition[2]	11	0.03	5.6%	11	0.03	10.0%	11	0.03	45.0%
Local Atmospheric Deposition[2]	1.2	0.003	0.6%	1.2	0.003	1.1%	1.2	0.003	4.7%
Sediment/ Deposited Mercury[3]	31	0.08	15.6%	43	0.1	38.9%	6.1	0.02	25.1%
Background									
Sediment/ Geologic Mercury[3]	153	0.4	78.2%	55	0.2	50.0%	6.1	0.02	25.1%
Watershed Total	196	0.5	100%	110	0.3	100%	24	0.07	100%
Watershed Reduction Factor[4]	1.3	—		1.3	—		1.3	—	
Target Watershed Load[5]	151	—		85	—		19	—	

[1] From Table 4.7
[2] From Table 4.3
[3] From Table 4.6
[4] From Table 4.8
[5] Target watershed load = watershed total/watershed reduction factor

Table 4.15. Estimated current mercury load for Lake Winona and Lake Sylvia watershed.

Source Type	Upper Boundary			Most Likely			Lower Boundary		
	Load		Percent of Total Load	Loading Rate		Percent of Total Load	Loading Rate		Percent of Total Load
	(g/yr)	(g/d)		(g/yr)	(g/d)		(g/yr)	(g/d)	
Point Source									
Municipal WWTPs[1]	0	0	0.0%	0	0	0.0%	0	0	0.0%
Non-Point Source									
Regional Atmospheric Deposition[2]	96	0.3	5.0%	96	0.3	9.0%	96	0.3	42.7%
Local Atmospheric Deposition[2]	8.0	0.02	0.4%	8.0	0.02	0.8%	8.0	0.02	3.6%
Sediment/ Deposited Mercury[3]	300	0.8	15.8%	420	1.1	39.5%	60	0.2	26.8%
Background									
Sediment/ Geologic Mercury[3]	1,499	4.1	78.8%	540	1.5	50.8%	60	0.2	26.8%
Watershed Total	1,903	5.2	100%	1,064	2.9	100%	224	0.6	100%
Watershed Reduction Factor[4]	1.1	—		1.1	—		1.1	—	
Target Watershed Load[5]	1,730	—		967	—		204	—	

[1] From Table 4.7
[2] From Table 4.3
[3] From Table 4.6
[4] From Table 4.8
[5] Target watershed load = watershed total/watershed reduction factor

Table 4.16. Fourche La Fave watershed TMDL allocation.

Source Type	Upper Boundary		Most Likely		Lower Boundary	
	Load (g/yr)	Percent of Total Load	Load (g/yr)	Percent of Total Load	Load (g/yr)	Percent of Total Load
Point Source						
Municipal WWTPs[1]	3.5	0.00%	3.5	0.01%	3.5	0.1%
Nonpoint Source						
Regional Atmospheric Deposition[2]	248	0.3%	248	0.5%	248	4.0%
Local Atmospheric Deposition[3]	67	0.1%	67	0.1%	67	1.1%
Sediment/Deposited Hg Erosion[4]	6,941	7.9%	11,180	23.9%	1,677	26.7%
Background						
Sediment/Geologic Mercury[5]	62,591	71.7%	25,925	55.4%	3,024	48.2%
Total Watershed Load	69,850	80.0%	37,423	80.0%	5,019	80.0%
Margin of Safety	17,462	20.0%	9,355	20.0%	1,255	20.0%
Total Maximum Load	87,312	100.0%	46,778	100.0%	6,274	100.0%

[1] WLA (g/yr) = flow (MGD) from Table 4.7 * 12ng/1 * 0.00037854 (conversion factor) * 365 days

[2] Regional Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.10 * 0.5

[3] Local Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.10 * (1-percent reduction from Table 4.22)

[4] Sediment/Deposited Mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate non-geologic mercury factor * 0.907185 (conversion factor) * (1-percent reduction factor form Table 4.23). Ther non-geologic mercury factors are 0.05 for the upper boundary, 0.07 for the most likely boundary and 0.01 for the lower boundary.

[5] Sediment/Geologic mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate rock mercury factor * 0.907185 (conversion factor). Rock mercury factors are 0.25 for the upper boundary, 0.09 for the most likely boundary and 0.01 for the lower boundary.

Table 4.17. Bayou Dorcheat watershed TMDL allocation.

Source Type	Upper Boundary Load (g/yr)	Upper Boundary Percent of Total Load	Most Likely Load (g/yr)	Most Likely Percent of Total Load	Lower Boundary Load (g/yr)	Lower Boundary Percent of Total Load
Point Source						
Municipal WWTPs[1]	51	0.1%	51	0.2%	51	1.1%
Nonpoint Source						
Regional Atmospheric Deposition[2]	1,448	3.7%	1,448	6.6%	1,448	30.5%
Local Atmospheric Deposition[3]	315	0.8%	315	1.4%	315	6.6%
Sediment/Deposited Hg Erosion[4]	2,831	7.3%	4,594	21.1%	691	14.6%
Background						
Sediment/Geologic Mercury[5]	26,484	68.1%	11,051	50.7%	1,294	27.3%
Total Watershed Load	31,129	80.0%	17,459	80.0%	3,799	80.0%
Margin of Safety	7,783	20.0%	4,365	20.0%	950	20.0%
Total Maximum Load	38,912	100.0%	21,824	100.0%	4,749	100.0%

[1] WLA (g/yr) = flow (MGD) from Table 4.7 * 12ng/1 * 0.00037854 (conversion factor) * 365 days

[2] Regional Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.11 * 0.5

[3] Local Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.11 * (1-percent reduction from Table 4.22)

[4] Sediment/Deposited Mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate non-geologic mercury factor * 0.907185 (conversion factor) * (1-percent reduction factor form Table 4.23). Ther non-geologic mercury factors are 0.05 for the upper boundary, 0.07 for the most likely boundary and 0.01 for the lower boundary.

[5] Sediment/Geologic mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate rock mercury factor * 0.907185 (conversion factor). Rock mercury factors are 0.25 for the upper boundary, 0.09 for the most likely boundary and 0.01 for the lower boundary.

Table 4.18. South Fork Little Red watershed TMDL allocation.

Source Type	Upper Boundary Load (g/yr)	Upper Boundary Percent of Total Load	Most Likely Load (g/yr)	Most Likely Percent of Total Load	Lower Boundary Load (g/yr)	Lower Boundary Percent of Total Load
Point Source						
Municipal WWTPs[1]	45	0.2%	45	0.4%	45	3.0%
Nonpoint Source						
Regional Atmospheric Deposition[2]	10	0.0%	10	0.1%	10	0.7%
Local Atmospheric Deposition[3]	1.3	0.0%	1.3	0.0%	1.3	0.1%
Sediment/Deposited Hg Erosion[4]	1,721	7.6%	2,775	23.2%	396	26.4%
Background						
Sediment/Geologic Mercury[5]	16,257	72.1%	6,740	56.3%	749	49.8%
Total Watershed Load	18,034	80.0%	9,571	80.0%	1,201	80.0%
Margin of Safety	4,508	20.0%	2,393	20.0%	300	20.0%
Total Maximum Load	22,542	100.0%	11,964	100.0%	1,501	100.0%

[1] WLA (g/yr) = flow (MGD) from Table 4.7 * 12ng/1 * 0.00037854 (conversion factor) * 365 days

[2] Regional Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.12 * 0.5

[3] Local Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.12 * (1-percent reduction from Table 4.22)

[4] Sediment/Deposited Mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate non-geologic mercury factor * 0.907185 (conversion factor) * (1-percent reduction factor form Table 4.23). Ther non-geologic mercury factors are 0.05 for the upper boundary, 0.07 for the most likely boundary and 0.01 for the lower boundary.

[5] Sediment/Geologic mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate rock mercury factor * 0.907185 (conversion factor). Rock mercury factors are 0.25 for the upper boundary, 0.09 for the most likely boundary and 0.01 for the lower boundary.

Table 4.19. Shepherd Springs Lake watershed TMDL allocation.

Source Type	Upper Boundary		Most Likely		Lower Boundary	
	Load (g/yr)	Percent of Total Load	Load (g/yr)	Percent of Total Load	Load (g/yr)	Percent of Total Load
Point Source						
Municipal WWTPs[1]	0	0.0%	0	0.0%	0	0.0%
Nonpoint Source						
Regional Atmospheric Deposition[2]	10	0.2%	10	0.4%	10	3.2%
Local Atmospheric Deposition[3]	2.5	0.0%	2.5	0.1%	2.5	0.8%
Sediment/Deposited Hg Erosion[4]	437	7.9%	611	23.8%	87	26.9%
Background						
Sediment/Geologic Mercury[5]	3,981	71.9%	1,433	55.7%	159	49.1%
Total Watershed Load	4,430	80.0%	2,056	80.0%	258	80.0%
Margin of Safety	1,108	20.0%	514	20.0%	64	20.0%
Total Maximum Load	5,538	100.0%	2,570	100.0%	322	100.0%

[1] WLA (g/yr) = flow (MGD) from Table 4.7 * 12ng/1 * 0.00037854 (conversion factor) * 365 days

[2] Regional Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.13 * 0.5

[3] Local Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.13 * (1-percent reduction from Table 4.22)

[4] Sediment/Deposited Mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate non-geologic mercury factor * 0.907185 (conversion factor) * (1-percent reduction factor form Table 4.23). Ther non-geologic mercury factors are 0.05 for the upper boundary, 0.07 for the most likely boundary and 0.01 for the lower boundary.

[5] Sediment/Geologic mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate rock mercury factor * 0.907185 (conversion factor). Rock mercury factors are 0.25 for the upper boundary, 0.09 for the most likely boundary and 0.01 for the lower boundary.

Table 4.20. Spring Lake watershed TMDL allocation.

Source Type	Upper Boundary Load (g/yr)	Upper Boundary Percent of Total Load	Most Likely Load (g/yr)	Most Likely Percent of Total Load	Lower Boundary Load (g/yr)	Lower Boundary Percent of Total Load
Point Source						
Municipal WWTPs[1]	0	0.0%	0	0.0%	0	0.0%
Nonpoint Source						
Regional Atmospheric Deposition[2]	5.5	2.9%	5.5	5.2%	5.5	29.0%
Local Atmospheric Deposition[3]	1.0	0.5%	1.0	1.0%	1.0	5.0%
Sediment/Deposited Hg Erosion[4]	14	7.4%	23	21.7%	3.3	16.0%
Background						
Sediment/Geologic Mercury[5]	130	69.2%	55	52.1%	6.1	30.0%
Total Watershed Load	150	80.0%	84	80.0%	16	80.0%
Margin of Safety	38	20.0%	21	20.0%	4.0	20.0%
Total Maximum Load	188	100.0%	105	100.0%	20	100.0%

[1] WLA (g/yr) = flow (MGD) from Table 4.7 * 12ng/1 * 0.00037854 (conversion factor) * 365 days

[2] Regional Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.14 * 0.5

[3] Local Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.14 * (1-percent reduction from Table 4.22)

[4] Sediment/Deposited Mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate non-geologic mercury factor * 0.907185 (conversion factor) * (1-percent reduction factor form Table 4.23). Ther non-geologic mercury factors are 0.05 for the upper boundary, 0.07 for the most likely boundary and 0.01 for the lower boundary.

[5] Sediment/Geologic mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate rock mercury factor * 0.907185 (conversion factor). Rock mercury factors are 0.25 for the upper boundary, 0.09 for the most likely boundary and 0.01 for the lower boundary.

Table 4.21. Lake Winona and Lake Sylvia watershed TMDL allocation.

Source Type	Upper Boundary Load (g/yr)	Upper Boundary Percent of Total Load	Most Likely Load (g/yr)	Most Likely Percent of Total Load	Lower Boundary Load (g/yr)	Lower Boundary Percent of Total Load
Point Source						
Municipal WWTPs[1]	0	0.0%	0	0.0%	0	0.0%
Nonpoint Source						
Regional Atmospheric Deposition[2]	48	2.2%	48	4.7%	48	26.1%
Local Atmospheric Deposition[3]	7.1	0.3%	7.1	0.7%	7.1	3.9%
Sediment/Deposited Hg Erosion[4]	159	7.4%	222	21.8%	32	17.3%
Background						
Sediment/Geologic Mercury[5]	1,499	70.0%	540	52.8%	60	32.7%
Total Watershed Load	1,713	80.0%	817	80.0%	147	80.0%
Margin of Safety	428	20.0%	204	20.0%	37	20.0%
Total Maximum Load	2,141	100.0%	1,021	100.0%	184	100.0%

[1] WLA (g/yr) = flow (MGD) from Table 4.7 * 12ng/1 * 0.00037854 (conversion factor) * 365 days

[2] Regional Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.15 * 0.5

[3] Local Atmospheric Deposition (g/yr) = current load (g/yr) from Table 4.15 * (1-percent reduction from Table 4.22)

[4] Sediment/Deposited Mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate non-geologic mercury factor * 0.907185 (conversion factor) * (1-percent reduction factor form Table 4.23). Ther non-geologic mercury factors are 0.05 for the upper boundary, 0.07 for the most likely boundary and 0.01 for the lower boundary.

[5] Sediment/Geologic mercury (g/yr) = reduced sediment load (tons/yr) from Table 4.24 * appropriate rock mercury factor * 0.907185 (conversion factor). Rock mercury factors are 0.25 for the upper boundary, 0.09 for the most likely boundary and 0.01 for the lower boundary.

Table 4.22. Expected reductions in local atmospheric mercury loads to airsheds due to implementation of MACT mercury emission regulations.

Airshed	Current Hg (II) (g/yr)	Reduced Hg (II) (g/yr)	Percent Reduction
Fourche La Fave River Airshed	293,103	272,926	6.9%
Bayou Dorcheat Airshed	255,316	199,780	21.8%
South Fork Little Red River Airshed	75,995	74,317	2.2%
Shepherd Springs Lake Airshed	146,378	145,064	0.9%
Spring Lake Airshed	99,163	85,595	13.7%
Lake Winona and Lake Sylvia Airshed	94,426	83,746	11.3%

Table 4.23. Reduction in mercury atmospheric deposition (regional and local) as a result of MACT mercury emission regulations implementation.

Watershed	Current Mercury Load (g/yr)	Reduced Mercury Load (g/yr)	Percent Reduction
Fourche La Fave	568	315	44.6%
Bayou Dorcheat	3,299	1,763	46.6%
South Fork Little Red River	22.4	11.3	47.1%
Shepherd Springs Lake	23.8	12.5	45.2%
Spring Lake	12.2	6.5	46.5%
Lake Winona and Lake Sylvia	104	55.1	47.0%

Table 4.24. Reductions in erosion rates for agricultural and barren land to achieve target watershed mercury loads, with reduced sediment loads.

Watershed	Reduced Erosion Rate[1] (tons/ac/yr)	Percent Reduction[2]	Reduced Sediment Load[3] (tons/yr)	Scenario
Fourche La Fave	1.47	38.9%	275,980	Upper Boundary
	1.86	22.6%	317,524	Most Likely
	2.01	16.4%	333,326	Lower Boundary
Bayou Dorcheat	1.15	52.1%	116,772	Upper Boundary
	1.44	39.8%	135,354	Most Likely
	1.56	35.0%	142,605	Lower Boundary
South Fork Little Red River	1.90	21.0%	71,683	Upper Boundary
Spring Lake	1.13	53.0%	575	Upper Boundary

Note: Sediment loads did not need to be reduced to achieve the target watershed mercury loads for Shepherd Springs Lake and the Lake Winona and Lake Sylvia watersheds, nor for the most likely and lower boundary scenarios for South Fork Little Red, and Spring Lake watersheds.

[1] Reduced agricultural and barren land erosion rate = 2.4, the original rate used in Table 4.5 * (1-percent reduction column value).

[2] Percent reduction was determined by iteratively trying different reductions until a watershed mercury load less than the target watershed mercury load was achieved.

[3] Reduced sediment load = (acres of agricultural land in watershed from Table 4.4 * reduced erosion rate above) + (acres of forest lands in watershed from Table 4.4 * 0.2, the original rate used in Table 4.5) + (acres of barren lands in watersed from Table 4.4 * reduced erosion rate above).

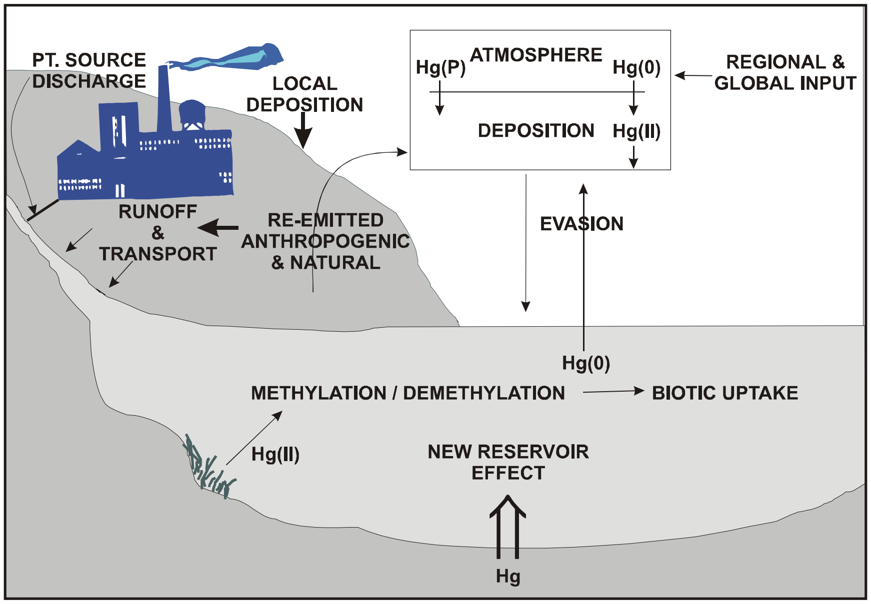


Figure 4.1. General mercury cycle showing atmospheric transport and deposition, point, nonpoint source and natural background contributions, and the effects of new reservoirs on mercury release into the environment (after Mason et.al. 1994).

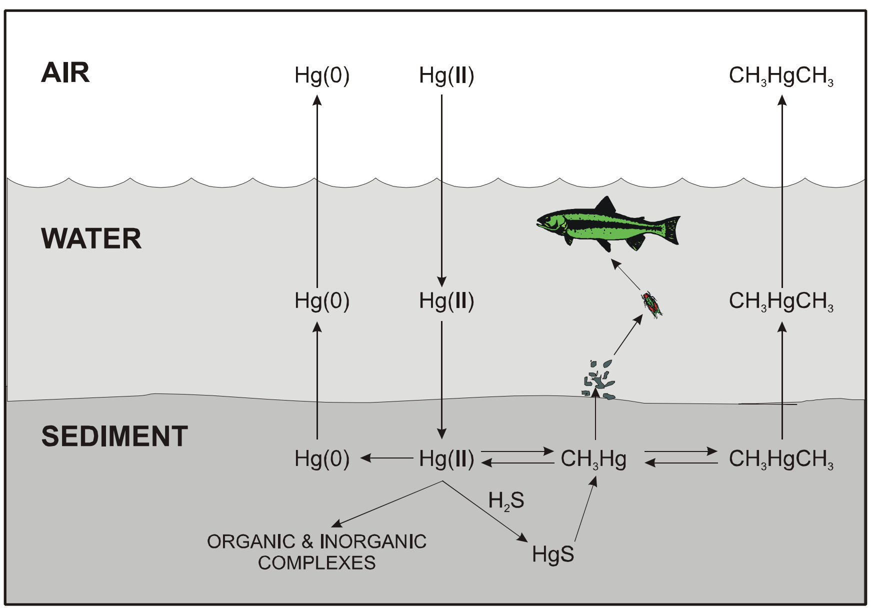


Figure 4.2. Pathways for mercury species through the aquatic ecosystem, including methylation and demethylation, evasion or loss from the water to the atmosphere, and sedimentation and burial in the sediment (After Winfrey and Rudd 1990).

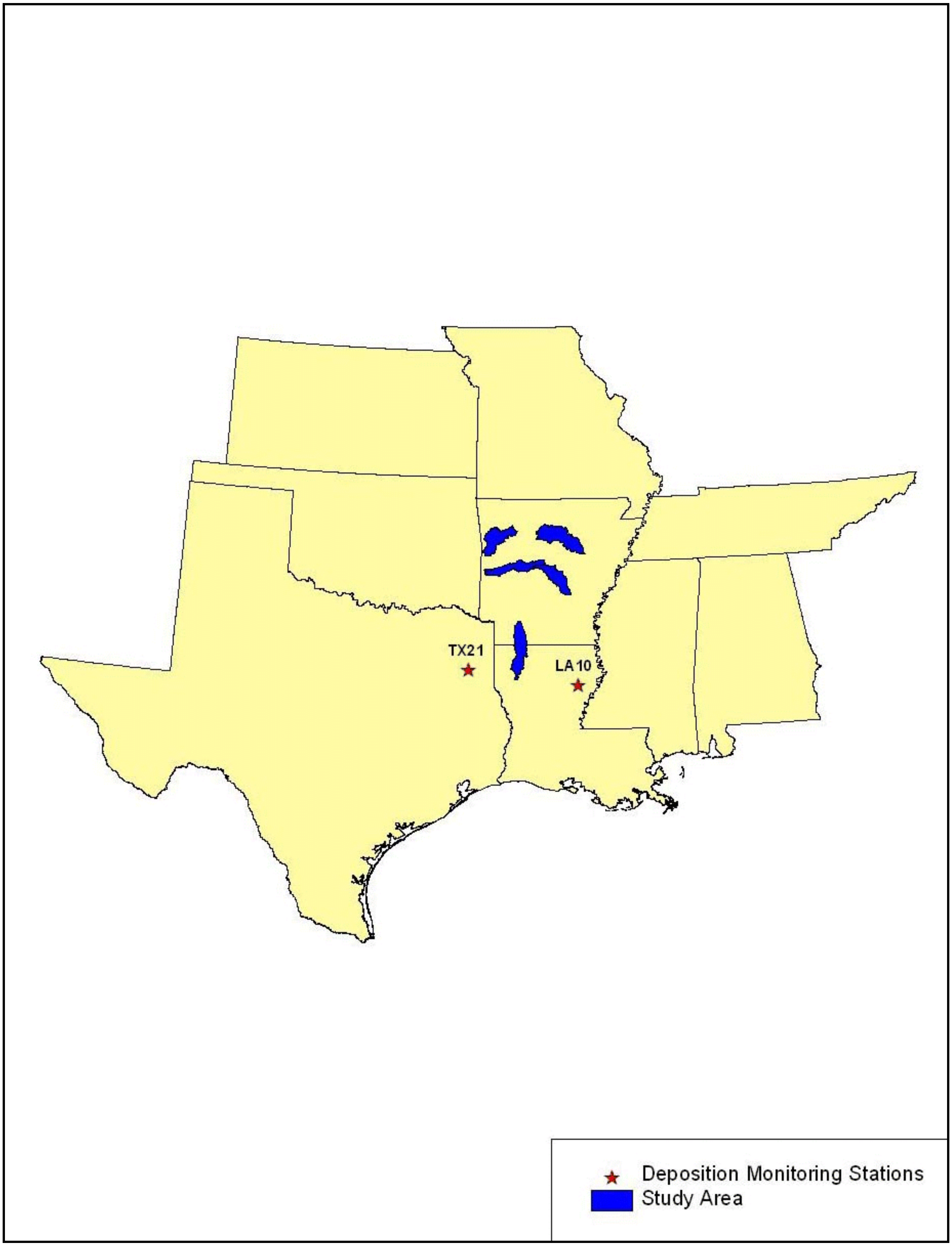


Figure 4.3. Location of National Atmospheric Deposition Program monitoring stations LA10 and TX21 relative to the HUCs included in this study.

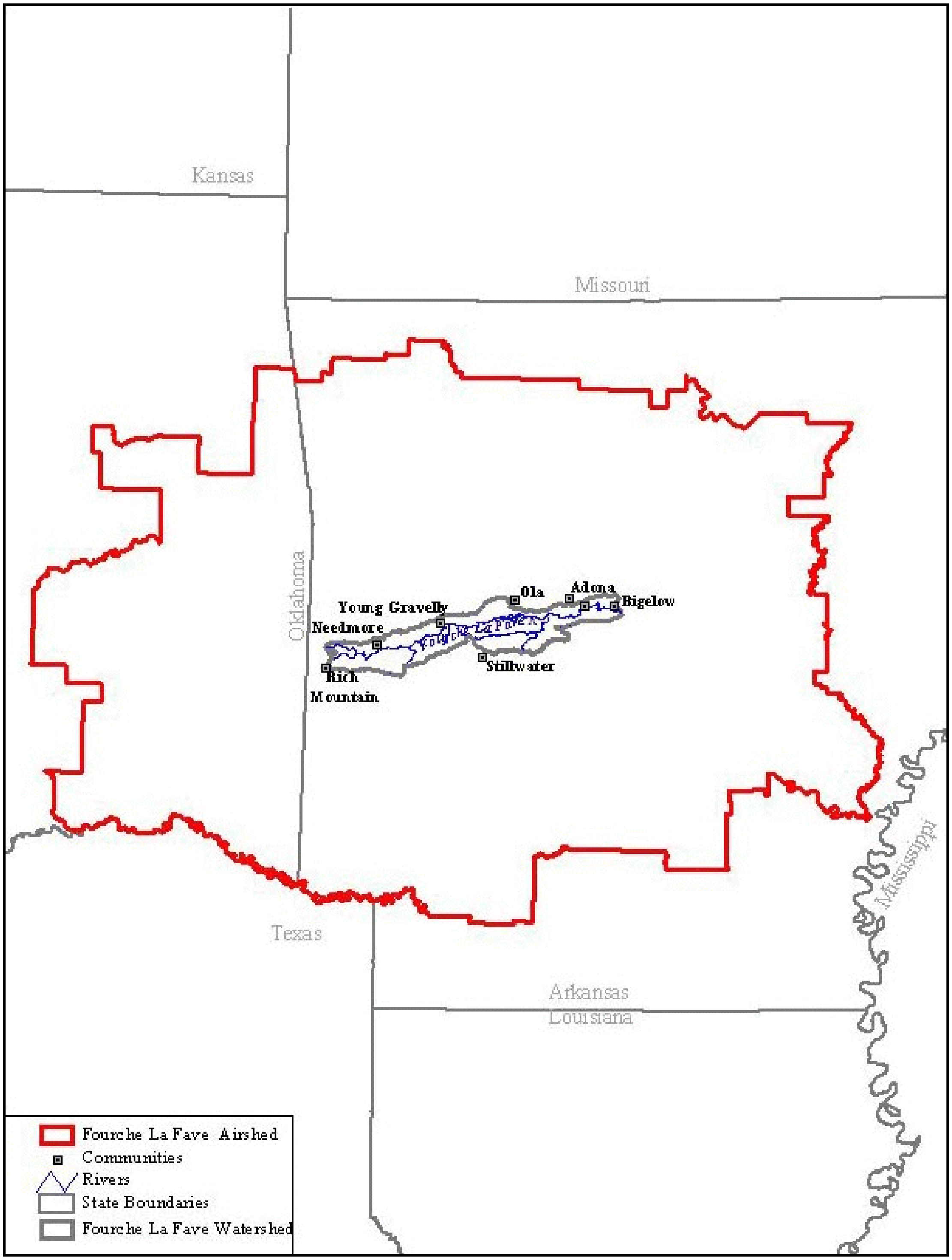


Figure 4.4. Airshed boundary for the Fourche La Fave watershed (includes all counties within 100 km of watershed).

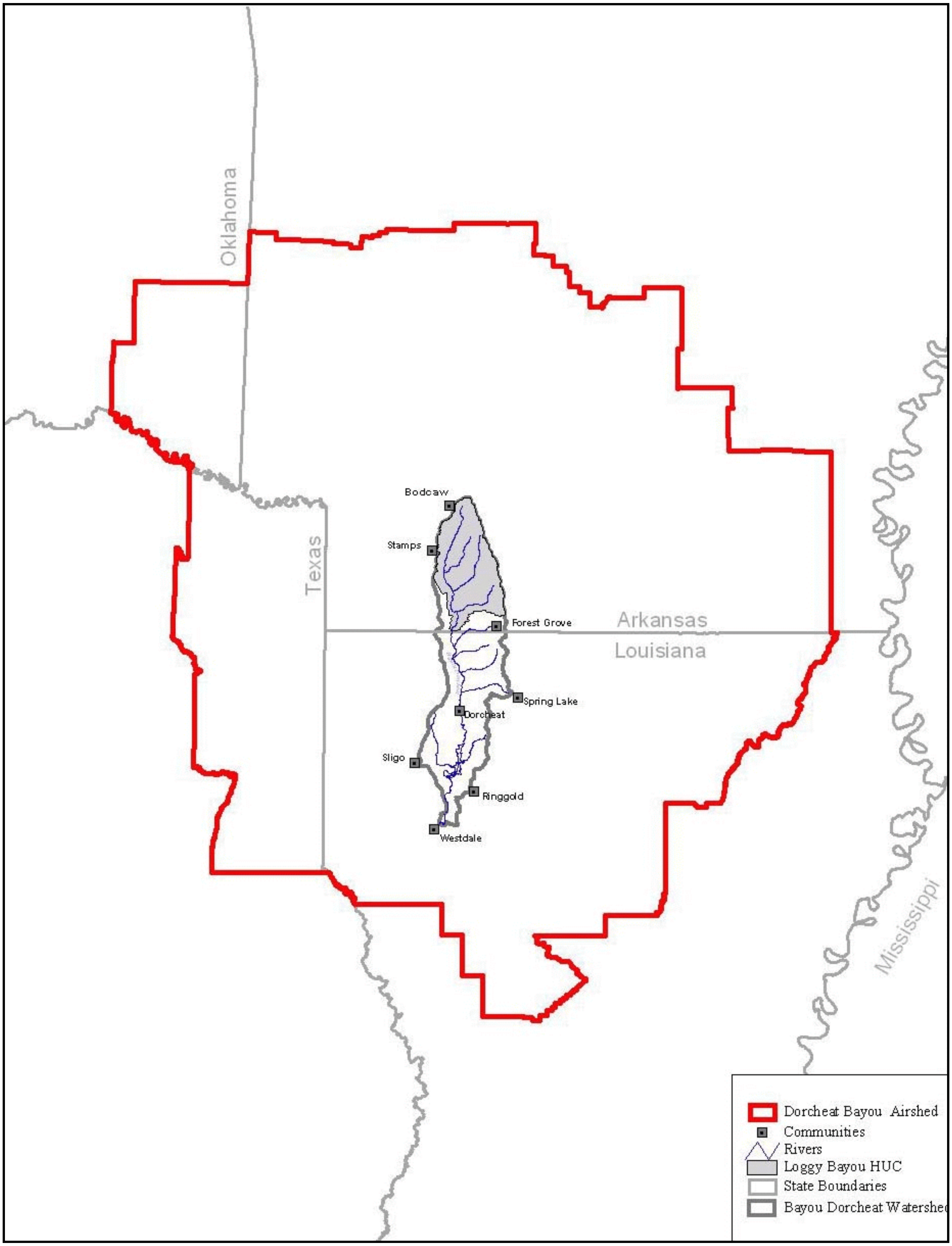
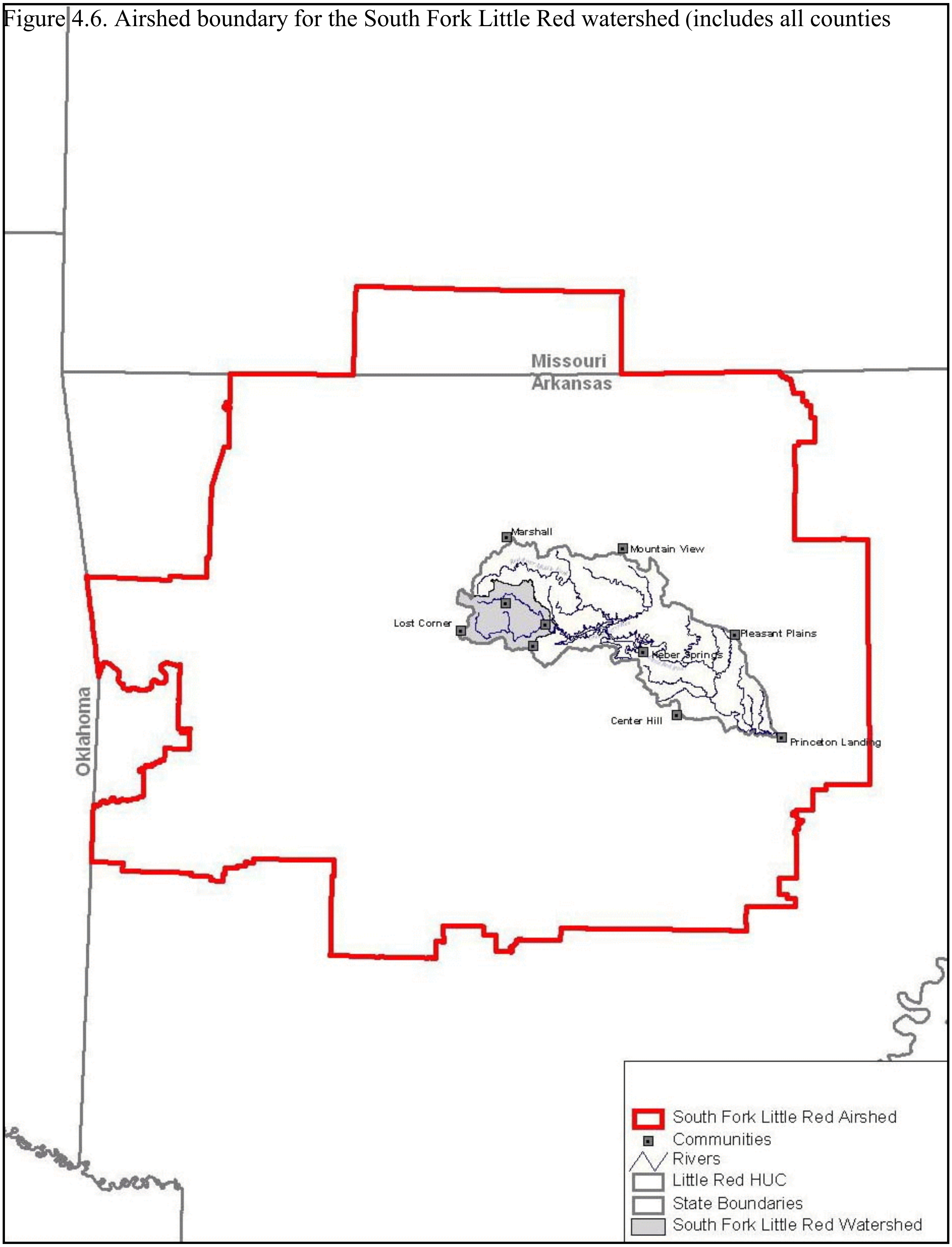


Figure 4.5. Airshed boundary for the Bayou Dorcheat watershed (includes all counties within 100 km of watershed).

Figure 4.6. Airshed boundary for the South Fork Little Red watershed (includes all counties within 100 km of watershed).



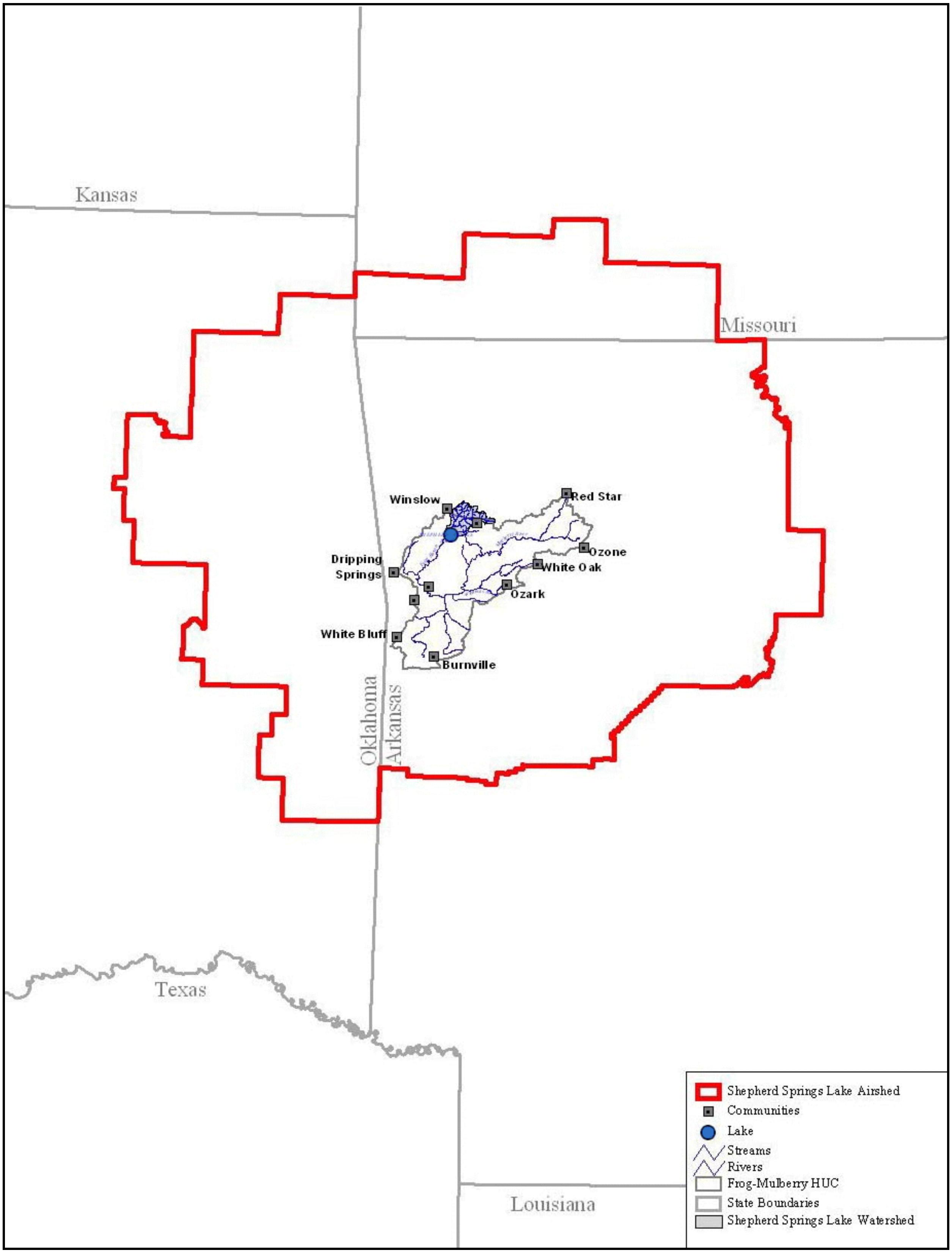


Figure 4.7. Airshed boundary for the Shepherd Springs Lake watershed (includes all coutnies within 100 km of watershed).

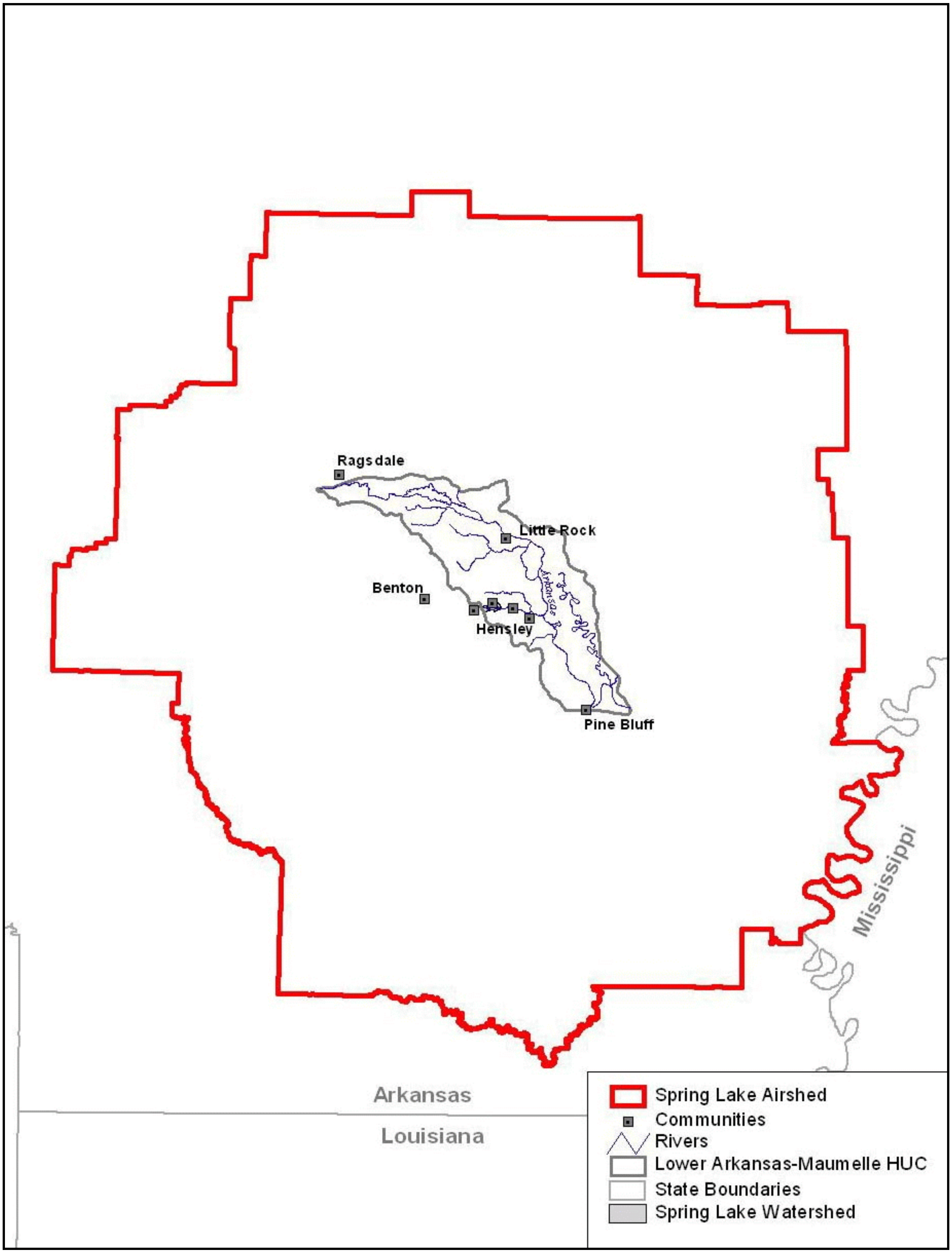


Figure 4.8. Airshed boundary for the Spring Lake watershed (includes all counties within 100 km of watershed).

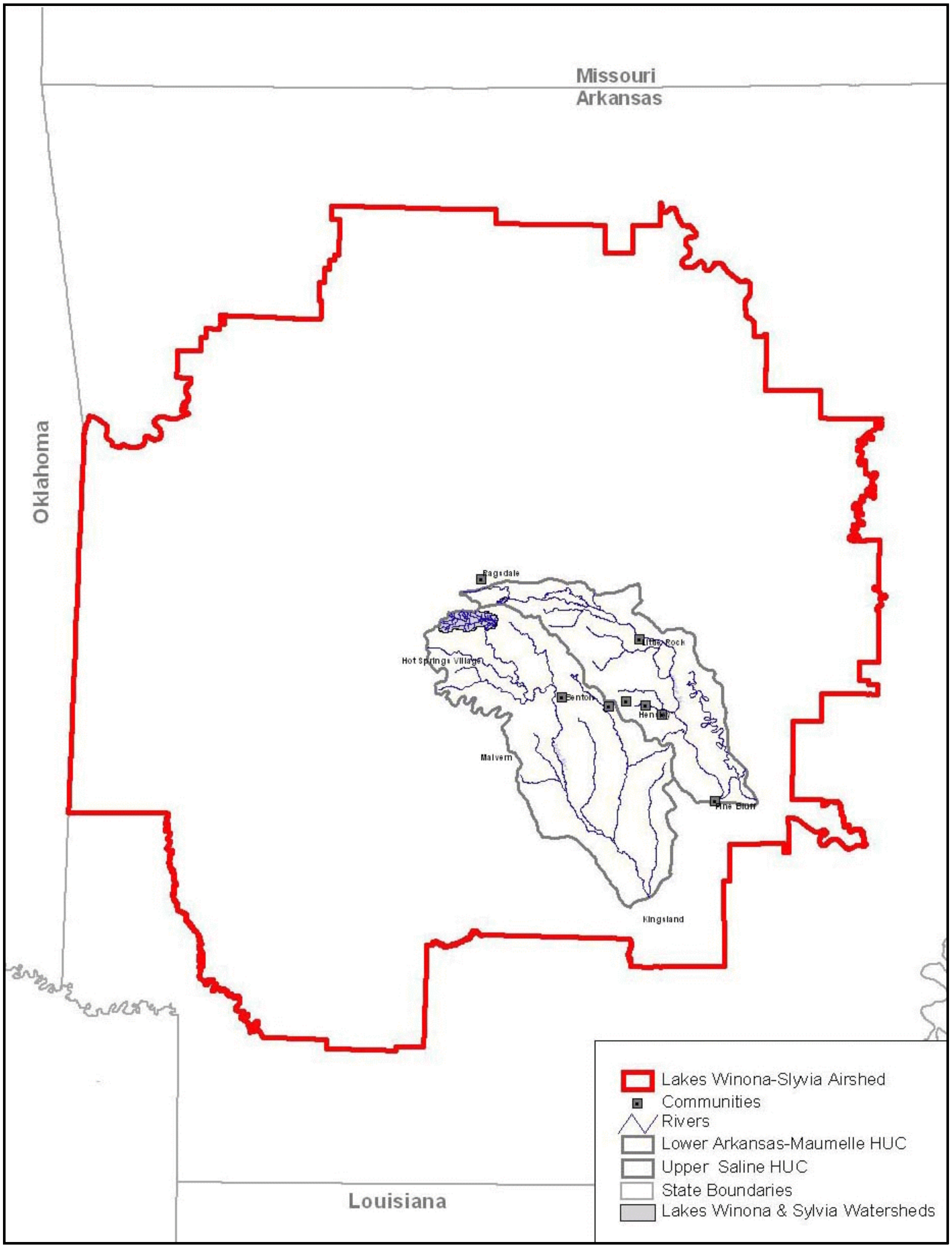


Figure 4.9. Airshed boundary for the Lake Winona and Lake Sylvia watershed (includes all counties within 100 km of watershed).

5.0 MARGIN OF SAFETY, SEASONAL VARIATIONS AND CRITICAL CONDITIONS

5.1 Margin of Safety

A margin of safety (MOS) accounts for any lack of knowledge or uncertainty concerning the relationship between load allocations and water quality. In these TMDLs, it accounts for uncertainty and variability related to fish tissue mercury concentrations, estimates of loading, and the assumption of a linear relationship between fish tissue concentration and watershed load. These TMDLs incorporated MOS in the reduction factors, the wasteload allocations, and the load allocations through conservative assumptions. Use of a safe target level of 0.8 mg/kg results in an explicit MOS of 20%. In addition, implicit MOS are included because only largemouth bass (trophic level 4) fish tissue mercury concentrations were used for estimating reductions rather than weighted trophic level fish tissue mercury concentrations accounting for expected human consumption ratios at each station. An advantage of using a regional approach is that waters which may be threatened by mercury (as opposed to impaired) are also protected. However, a limitation of the approach is that watershed-specific TMDLs might not sufficiently address long-range emissions which contribute to bioaccumulation of mercury. Regulatory mechanisms to address mercury on a national and/or global scale are needed.

5.2 Seasonal Variations and Critical Conditions

Wet deposition is greatest in the winter and spring seasons. Mercury loads fluctuate based on the amount and distribution of rainfall, and variability of localized and global/regional sources. While an average daily load is established here, the average annual load is of greatest significance because mercury bioaccumulates over the life of the fish and the resulting risk to human health from fish consumption is a long-term phenomenon. Thus, daily or weekly inputs are less meaningful than total annual loads over many years. The use of annual loads allows for integration of short-term and seasonal variability. Inputs should continue to be estimated through wet deposition and additional monitoring.

Mercury methylation is expected to be highest during the summer. High temperatures promote biological activity and lakes and reservoirs are stratified with anoxic hypolimnions. Based on the enhanced methylation and higher predator feeding rates during this period, mercury bioaccumulation is expected to be greatest during the summer. However, given the long depuration times for fish and relatively mild winters in Arkansas, seasonal changes in fish tissue mercury body burden are expected to be relatively small. Inherent variability of mercury concentrations between individual fish of the same and/or different size categories is expected to be greater than seasonal variability.

Because of local geology, soils, natural vegetation, and topography, some areas are more susceptible to mercury methylation than others.

6.0 REASONABLE ASSURANCE: ONGOING AND FUTURE REDUCTIONS IN EMISSIONS

Reasonable assurance is needed that water quality standards will be attained. Mechanisms to assess and control mercury loads, including strategies and regulatory controls, which would be national in scope, will aid implementation of TMDLs for specific basins. In addition, these TMDLs will be reassessed periodically and may be modified to take into account available data and information, and the state of the science.

As rules and standards pursuant to the Clean Air Act have been developed, proposed, and promulgated since 1990, compliance by emitting sources as well as actions taken voluntarily have already begun to reduce emissions of mercury to the air across the US. EPA expects a combination of ongoing activities will continue to reduce mercury emissions to the air over the next decade. EPA currently regulates emissions of mercury and other hazardous air pollutants (HAPs) under the maximum achievable control technology (MACT) program of Section 112 of the Clean Air Act, and under a corresponding new source performance standard (NSPS) program under Sections 111 and 129 of the Act. Section 112 authorizes EPA to address categories of major sources of HAPs, including mercury, by issuing emissions standards that, for new sources, are at least as stringent as the emissions control achieved by the best performing similar source in the category, and, for existing sources, are at least as stringent as the average of the best performing top 12% (or 5 facilities whichever is greater) of similar sources. EPA may also apply these standards to smaller area sources, or choose to apply less stringent standards based on generally available control technologies (GACT). Sections 111 and 129 direct EPA to establish MACT-equivalent standards for each category of new and existing solid waste incineration units, regulating several specified air pollutants, including mercury. In addition, in 1996 the US eliminated the use of mercury in most batteries under the Mercury Containing and Rechargeable Battery Management Act. This action is reducing the mercury content of the waste stream which is further reducing mercury emissions from waste combustion. In addition, voluntary measures to reduce use of mercury containing products, such as the voluntary measures committed to by the American Hospital Association, also will contribute to reduced emissions from waste combustion.

Based on the EPA's National Toxics Inventory, the highest emitters of mercury to the air include coal-burning electric utilities, municipal waste combustors, medical waste incinerators, chlor-alkali plants, and hazardous waste combustors. EPA has issued a number regulations under Sections 112, 111, and 129 to reduce mercury pollution from several of these source categories. Relevant regulations that EPA has established to date under the Clean Air Act include, among others, those listed below.

- The source category of municipal waste combustion (MWC) emitted about 20% of total national mercury emissions into the air in 1990. EPA issued final regulations under Sections 111 and 129 for large MWCs on October 31, 1995. Large combustors or incinerators must comply with the rule by December, 2000. These regulations reduce mercury emissions from these facilities by about 90% from 1990 emission levels.

- Medical waste incinerators (MWIs) emitted about 24% of total national mercury emissions into the air in 1990. EPA issued emission standards under Sections 111 and 129 for MWIs on August 15, 1997. When fully implemented, in 2002, EPA's final rule will reduce mercury emissions from MWIs by about 94% from 1990 emission levels.

- Hazardous waste combustors (HWCs) emitted about 2.5% of total national mercury emissions in 1990. In February 1999, EPA issued emission standards under Section 112 for these facilities, which include incinerators, cement kilns, and light weight aggregate kilns that burn hazardous waste. When fully implemented, these standards will reduce mercury emissions from HWCs by more than 50% from 1990 emission levels.

These promulgated regulations when fully implemented and considered together with actions discussed above that will reduce the mercury content of waste are expected to reduce national mercury emissions caused by human activities by about 50% from 1990 levels.

In February 2002 President Bush announced the Clear Skies Initiative. This initiative proposed to reduce mercury emissions from power plants (electric utilities) by 69%. An intermediate cap of 26 tons of mercury per year was proposed for 2010. Current mercury emissions from power plants are 48 tons per year.

EPA expects to propose a regulation under Section 112 that will limit mercury emissions from chlor-alkali plants, chlorine production facilities which use the mercury cell technology. In addition, under the Integrated Urban Air Toxics Strategy, which was published in 1999, EPA is developing emissions standards under Section 112 for categories of smaller sources of air toxics, including mercury, that pose the greatest risk to human health in urban areas. These standards are expected to be issued by 2004.

It is possible that the cumulative effect of additional standards and voluntary actions will reduce mercury emissions from human activities in the US by more than 50% from 1990 levels. However, whether the overall, total percent reduction in national mercury emissions in the future will exceed 50% cannot be estimated at this time. EPA will continue to track emissions of mercury and evaluate additional approaches to reduce releases of mercury into the environment.

Because of the persistence of mercury in tissue, it could take decades for mercury levels in predatory fish to drop as a result of reductions in mercury loading to the watersheds. Changes in factors such as levels of sulfate, TOC, pH, and DO, that affect methylation may cause some sites to react more slowly to reductions in mercury loads. Also, the age of the reservoirs in this TMDL study will affect how they react to reductions in mercury loads. It typically takes 20 to 30 years for organic matter concentrations in new reservoirs to drop below levels that are suitable for supporting methylating bacteria. Therefore, an adaptive management approach is recommended for the watersheds included in this TMDL study. This approach would include public education on the potential effects and sources of mercury, implementation of BMPs, and management of fisheries based on local characteristics. The goal should be to move toward use attainment while protecting human health.

The environmental indicators that will be used to evaluate success will be monitoring of wet deposition rates at the LA10 site and monitoring fish tissue mercury concentrations in the watersheds. Initiation of long term mercury deposition monitoring in Arkansas would improve estimates of existing mercury loadings, and tracking of mercury reductions.

7.0 PUBLIC PARTICIPATION

When EPA establishes a TMDL, 40 CFR §130.7(d)(2) requires EPA to publicly notice and seek comment concerning the TMDL. These TMDLs were prepared under contract to EPA. After completion of these draft TMDLs, EPA will commence preparation of a notice seeking comments, information and data from the general and affected public. If comments, data, or information are submitted during the public comment period, then the TMDLs may be revised accordingly. After considering public comment, information, and data, and making any appropriate revisions, EPA will transmit the revised TMDLs to ADEQ for incorporation into the ADEQ current water quality management plan.

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